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TP 4694E

Economic Low-Capacity Secondary Surveillance Radar

Summary Report

Prepared for the
Transportation
Development Centre
Transport Canada

May 1983

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TP# 4694E

ECONOMIC LOW-CAPACITY SECONDARY SURVEILLANCE RADAR

Summary Report

Prepared for
Transportation Development Centre
May 1983

By: Darius Vakili, P.Eng.
Canadian Astronautics Limited

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17. Abstract

An investigation of the concept of low-traffic capacity Secondary Surveillance Radar (SSR) for applications in small airports and remote Unattended NAVigation COMmunication (UNAVCOM) stations is conducted. Different modes of application of this radar are identified and complete technical designs along with their cost estimates are presented.

The proposed design consists of an Antenna Unit, L-Band Transmitter/Receiver Unit, Data Acquisition Unit and six different Display/Report options. These options output the radar detections in the form of text report, area traffic map, remote data transmission and synthesized voice announcement. Guidance for proper selection of the option(s). for different radar installations is also given in their technical description.

A particular option, the Talkback SSR (TSSR), is described for application in UNAVCOM stations. This option reports the radar detection back to the pilot, by synthesized voice, on the aircraft VHF radio. The description includes operation methods of the TSSR and related problems with transponder code assignment. Also, a comparison of the TSSR with Talkback radio Direction Finder (TDF) is presented.

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17. Résumé

Un radar de veille secondaire peu coûteux pour trafic aérien faible. On présente une étude du concept de Radar de veille secondaire (RVS) pour traffic aérien faible en vue d'applications dans les petits aéroports et les stations de communications d'aide à la navigation sans surveillance (UNAVCOM). Le résultat de l'étude est l'identification de plusieurs modes différents d'application du radar pour lesquels on présente les projets techniques complets et l'estimation des coûts.

Le concept proposé comprend l'élément antenne, l'élément émetteur/récepteur en bande L, l'élément saisie des données ainsi que six options différentes pour l'affichage et les communications écrites. Ces options sortent les détections radar sous forme de communication écrite, de carte de traffic de la zone, de/transmission des données à distance et de message vocal synthétique. Dans la description technique de ces options, on donne aussi des indications quant au choix approprié d'une ou plusieurs d'entre elles suivant le type d'installation radar envisagée.

On décrit en particulier une option spécifique, le RVS à réponse parlée (RVSRP) pour l'application dans les stations UNAVCOM. Cette option communique la détection radar au pilote par voix synthétique, sur la radio THF de l'aéronef. La description comprend notamment une discussion des méthodes operation applicables au RVSRP et de certains problèmes relatifs à l'attribution des codes aux transpondeurs. On présente également une comparaison du RVSRP avec le radiogoniomètre réponse parlée.

18. Mots-clés	19. Diffusion
Radar secondaire, RVS, RVSRP, RVS à réponse parlée, radar IFF, balise radar, transpondeur radar.	Le CDT dispose d'une nombre limité d'exemplaires.

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FOREWORD

The idea of a low-traffic density secondary surveillance Radar (SSR) was identified during a system study for Unattended NAVigation COMmunication (UNAVCOM) stations, under a contract for Transportation Development Centre (TDC).

This Radar could be used, as a navigation aid, in small manned airports or in remote UNAVCOM stations. In the latter service, the radar sends the display data to a manned station by some communication means or functions as talkback unit, reporting the aircraft position back to the pilot, on the VHF radio by synthesized voice.

This radar consists of an Antenna Unit, Transmitter/Receiver Unit, Data Acquisition Unit, and the Power Supply; in a standard 19" rack. The rack can also house one or more of the following display/report options.

1) Text Display Option: It presents the aircraft identification and position in the form of a line text on a CRT monitor or record them on a line printer.

2) PPI Display Option: The information is displayed on a Plan Position Indicator.

3) Raster Scan Display Option: The information is presented in a format similar to PPI, however, it is outputted to an ordinary TV monitor in the raster scan form.

4) Remote Reporting Option: The radar findings are sent, by a modem, to a manned control centre by a telephone line.

5) Talk-Back Option: The aircraft identification and its position are reported, with synthesized voice, back to the pilot through the aircraft VHF radio. This is the proposed version of SSR for UNAVCOM stations intednad for the remote Arctic regions.

6) Annunciator option: The aircraft I.D. and position is announced, with synthesized voice, on a speaker. It is purposed for air-traffic control stations where the controllers have other duties while monitoring the traffic.

Technically, the directional Antenna Unit could be Electronically (E-Scan) or a mechanically scanned (M-Scan) dipole array arrangement having a gain of 30. It features a fan beam of 10 degree azimuth and 55° elevation beamwidth. This antenna could be designed to be a monopulse unit or work in conjunction with an omni-directional antenna.

The transmitter consists of a crystal controlled L-band (1030 MHz) oscillator, a PIN diode modulator, solid-state (transistorized) power amplifier, and a PIN diode side-lobe suppression (SLS) power switch.

The receiver is a super hetrodyne 1090 MHz unit with the 1030 MHz transmitter oscillator used for mixer (60 MHz I.F.). It features a log amplifier, a video envelope detector, and a video processor for shaping the video pulses.

The Data Acquisition Unit consists of digital circuitry to decode the transponder pulse train in order to obtain the aircraft inforamtion and its range and azimuth position. These information are handed to Display/Report options for the proper operator interface.

The Display/Report options are all microcomputer based units. They convert the received radar detections to the desired display or report format and output them to the CRT displays, printer, recorders, and synthesized voice announcement equipment.

The radar with one option is estimated to cost approximately $440,000 for developing the first prototype or have a product price tag of about $110,000 after the development, with the development cost spread over 30 similar units. Also, a development schedule is presented in the report which summarizes the time arrangement to develop such a radar with a personnel of 10 engineers and technicians.

The preliminary design of this radar was prepared and reviewed with potential future users and their views and recommendations was entered in the design process. The final results of the reviews are given in the report and summarized below.

RESULTS

The radar and its options was considered very attractive by the users. There was some concern by the transportation authorities as to the reluctance of the small aircraft pilotes to buy an SSR transponder. However, in discussions with the owners and pilots of such aircrafts, no appreciable oposition was noticed and the service available from the SSR was considered to be worth of the investment in a transponder.

Further, the Talkback SSR (TSSR) was considered to be more useful than the Talkback Radio Direction Finder (TDF).

CONCLUSION

The application of a Talkback SSR for UNAVCOM is strongly recommended. The design of the radar along with its development time and cost is given in the report. It is possible to develop this radar to the first prototype (with only one option) at a cost of approximately $440,000 and time of one year. Of course after development the price tag for the system would be around $110,000 (for 30 similar units).

RECOMMENDATIONS

The Talkback SSR (TSSR) is strongly recommended for a UHAVCOM facility. It provides both range and azimuth angle also it detects the aircraft altitude (if aircraft transponder is interfaced with the altimeter), radio failure and other emergencies.

The recommendation for the transponder codes is to use the standard 1200 code unless being warned by the TSSR for the case of more than two aircrafts in the field. In such a situation the two aircrafts can use different codes or activate SPI switch one-by-one to obtain the TSSR service without confusion.

TP# 4571E

ECONOMIC LOW-CAPACITY SECONDARY SURVEILLANCE RADAR

Prepared for
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May 1983

By: Darius Vakili, P.Eng.
Canadian Astronautics Limited

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17. Résumé Un radar de veille secondaire peu coûteux pour trafic aérien faible.

On présente une étude du concept de Radar de veille secondaire (RVS) pour traffic aérien faible en vue d'applications dans les petits aéroports et les stations de communications d'aide à la navigation sans surveillance (UNAVCOM). Le résultat de l'étude est l'identification de plusieurs modes différents d'application du radar pour lesquels on présente les projets techniques complets et l'estimation des coûts.

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PREFACE

The concept of using a low capacity economic Talkback Secondary Surveillance Radar (SSR) was identified during a study for the Unattended Navigation Communication (UNAVCOM) project which was undertaken by Canadian Astronautics Limited for Transportation Development Centre (TDC). The concept turned out to be very attractive for such an application.

The current report is an extension of this concept, namely, it is the study of concept of a low capacity economic SSR (not necessarily only a talkback one) for applications in small airports, mobile/shipborne air-traffic and defense systems, as well as remote and unattended stations, in the talkback or report mode.

The study provides a preliminary design and technical specification for the radar. The design investigates different information output equipment such as different types of CRT displays, printers, recorders, annunciators and remote communication units.

Further, the above preliminary design and specification was discussed and reviewed with the potential future users of the proposed SSR, such as Transport Canada, pilots, air traffic controllers, airport authorities, flight safety experts and Department of National Defence.

As a result, the preliminary design was refined and defined to the point where the development is made feasible.

Moreover, the purpose of current work is to define the technical characteristics of a new product, as an optional navigation aid. The intention is not, in any way, to propose policies for transportation authorities so as to mandate the use of SSR transponder or any other equipment.

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	USER'S VIEW OF THE LOW-CAPACITY SSR	4
2.1	AS A NAVIGATION AID AT SMALL AIRPORTS	4
2.2	AS COMPONENT IN CENTRALIZED AIR-TRAFFIC MONITORING SYSTEM	4
2.3	AS A TAKING AND ANNUNCIATOR RADAR	5
2.4	AS A TALKBACK RADAR (TSSR)	5
2.4.1	RADIO LOGIN PROCEDURE	6
2.4.2	CODE ASSIGNMENT WITH THE FLIGHT PLAN	7
2.4.3	TSSR WARNING THE PILOTS TO COOPERATE	8
3.0	SYSTEM DESIGN DESCRIPTION	9
3.1	ANTENNA UNIT	9
3.1.1	E-SCAN ANTENNA	10
3.1.2	M-SCAN ANTENNA	10
3.2	INTERROGRATOR UNIT	13
3.2.1	CODER MODULE	13
3.2.2	TRANSMITTER MODULE	16
3.2.3	RECEIVER MODULE	16
3.2.4	VIDEO PROCESSOR MODULE	20
3.2.5	FAULT MONITORING	20

			Page
3.3	DATA ACQUISITION UNIT		22
	3.3.1	FRAME DECODER	22
	3.3.2	GARBLE REJECTION FILTER	24
	3.3.3	RESPONSE SHIFT REGISTER	24
	3.3.4	RESPONSE MULTIPLEXERS	24
	3.3.5	RESPONSE REGISTERS	27
	3.3.6	SPI DECODER	27
	3.3.7	RANGE DECODER	27
	3.3.8	AZIMUTH DECODER	27
	3.3.9	SSR STATUS REPORT PORT	28
	3.3.10	HANDSHAKE AND SUPERVISORY LOGIC	28
	3.3.11	CODE PROCESSOR	28
	3.3.12	THE IMPLEMENTATION OF DATA ACQUISITION UNIT	29
	3.3.13	SIMPLIFIED DATA ACQUISITION UNIT	29
3.4	DISPLAY/REPORT UNITS		32
	3.4.1	TEXT DISPLAY UNIT	32
	3.4.2	PPI DISPLAY UNIT	33
	3.4.3	RASTER SCAN DISPLAY UNIT	36
	3.4.4	REMOTE REPORT UNIT	36
	3.4.5	ANOUNCIATOR REPORT UNIT	37
	3.4.6	THE TALKBACK UNIT	42
4.0	COST AND TIME ESTIMATES		44
4.1	PRODUCT COST		44
	4.1.1	ANTENNA UNIT	44
	4.1.2	INTERROGATOR UNIT	45
	4.1.3	DATA ACQUISITION UNIT	45

		Page
4.1.4	DISPLAY/REPORT OPTIONS	46
	• TEXT DISPLAY UNIT	46
	• PPI DISPLAY UNIT	46
	• RASTER SCAN DISPLAY UNIT	47
	• REMOTE/REPORT UNIT	47
	• ANNOUNCIATOR REPORT UNIT	48
	• TALKBACK UNIT	48
	• REMOTE DISPLAY UNITS	49
4.2	DEVELOPMENT COST AND TIME	49
4.2.1	ANTENNA UNIT	49
4.2.2	INTERROGATOR UNIT	51
4.2.3	DATA ACQUISITION UNIT	51
4.2.4	DISPLAY/REPORT UNIT	51
	• TEXT DISPLAY UNIT	51
	• PPI DISPLAY UNIT	52
	• RASTER SCAN DISPLAY UNIT	52
	• REMOTE/REPORT UNIT	52
	• ANNOUNCIATOR REPORT UNIT	53
	• TALKBACK UNIT	53
	• REMOTE DISPLAY UNITS	53
4.3	COST OF AN SSR SYSTEM	53
4.3.1	AN ECONOMY SSR FOR SMALL MANNED AIRPORTS	54
4.3.2	TALKBACK SSR FOR UNAVCOM	54
4.4	DEVELOPMENT COST OF AN SSR SYSTEM	55
4.4.1	ECONOMY SSR	55
4.4.2	TALKBACK SSR	55

		Page
5.0	POWER CONSUMPTION OF THE RADAR	56
5.1	ANTENNA UNIT	56
5.2	INTERROGATOR UNIT	57
5.3	DATA ACQUISITION UNIT	57
5.4	POWER CONSUMPTION OF THE OPTIONS	57
5.5	POWER CONSUMPTION OF AN SSR SYSTEM	59
6.0	COMPARISON OF SSR AND DF FOR UHAVCOM	61
6.1	OPERATIONAL CONSIDERATIONS	61
6.2	PERFORMANCE CONSIDERATIONS	62
6.3	TECHNICAL AND ECONOMIC CONSIDERATIONS	63
7.0	RESULTS	64
8.0	SUMMARY	65
9.0	RECOMMENDATIONS	67
	REFERENCES	70
	OTHER COMPANIES INVOLVED IN ECONOMIC S3R	71

LIST OF FIGURES

		Page
FIGURE 1	LOW-CAPACITY SSR FAMILY EQUIPMENT	2
FIGURE 2	DESIGN CONCEPT OF THE E-SCAN DIRECTIONAL ANTENNA	11
FIGURE 3	DESIGN CONCEPT OF THE M-SCAN DIRECTIONAL ANTENNA	12
FIGURE 4	BLOCK-DIAGRAM OF THE INTERROGATOR UNIT	14
FIGURE 5	BLOCK-DIAGRAM OF THE CODER MODULE	15
FIGURE 6	CONCEPTUAL DESIGN OF THE TRANSMITTER	17
FIGURE 7	SSR PULSE TIMING DIAGRAM	18
FIGURE 8	CONCEPTUAL DESIGN OF THE RECEIVER	19
FIGURE 9	CONCEPTUAL DESIGN OF THE VIDEO PROCESSOR	21
FIGURE 10	BLOCK-DIAGRAM OF THE DATA ACQUISITION UNIT	23
FIGURE 11	PULSE TIMING DIAGRAM OF GARBLE	25
FIGURE 12	CONCEPTUAL DESIGN OF A GARBLE FILTER	26
FIGURE 13	IMPLEMENTATION OF THE DATA ACQUISITION	30
FIGURE 14	SIMPLIFIED DATA ACQUISITION UNIT	31
FIGURE 15	CONCEPTUAL DESIGN OF THE TEXT DISPLAY UNIT	34
FIGURE 16	CONCEPTUAL DESIGN OF THE PPI DISPLAY UNIT	35
FIGURE 17	CONCEPTUAL DESIGN OF THE RASTER SCAN DISPLAY UNIT	37
FIGURE 18	CONCEPTUAL DESIGN OF THE REMOTE REPORT UNIT	39
FIGURE 19	CONCEPTUAL DESIGN OF THE REMOTE DISPLAY UNIT	40
FIGURE 20	CONCEPTUAL DESIGN OF THE ANNOUNCIATOR REPORT UNIT	41
FIGURE 21	CONCEPTUAL DESIGN OF THE TALKBACK UNIT	43
FIGURE 22	TSSR DEVELOPMENT TIME SCHEDULE	50

LIST OF TABLES

		Page
Table 4-1	E-Scan Antenna Cost	44
4-2	M-Scan Antenna Cost	44
4-3	Interrogator Unit Cost	45
4-4	Data Acquisition Unit Cost	45
4-5	Text Display Unit Cost	46
4-6	PPI Display Unit Cost	46
4-7	Raster Scan Display Unit Cost	47
4-8	Remote Report Unit Cost	47
4-9	Annunciator Report Unit Cost	48
4-10	Talkback Unit Cost	48
4-11	E-Scan Antenna Development Cost	49
4-12	M-Scan Antenna Development Cost	49
4-13	Interrogator Unit Development Cost	51
4-14	Data Acquisition Unit Development Cost	51
4-15	Text Display Unit Development Cost	51
4-16	PPI Display Unit Development Cost	52
4-17	Raster Scan Display Unit Development Cost	52
4-18	Remote Report Unit Development Cost	52
4-19	Annunciator Report Unit Development Cost	53
4-20	Talkback Unit Development Cost	53
4-21	Unit Price for an Economic SSR	54
4-22	Unit Price for a TSSR	54
4-23	Development Cost for the Economic SSR	55
4-24	Development Cost for the TSSR	55
Table 5-1	Antenna Unit Power Consumption	56
5-2	Interrogator Unit Power Consumption	56
5-3	Data Acquisition Unit Power Consumption	57
5-4	Text Display Unit Power Consumption	57
5-5	PPI Display Unit Power Consumption	58
5-6	Raster Scan Display Unit Power Consumption	58
5-7	Remote Report Unit Power Consumption	58
5-8	Annunciator Unit Power Consumption	59
5-9	Talkback Unit Power Consumption	59
5-10	Power Consumption of the Economic SSR	59
5-11	Power Consumption of the UNAVCOM TSSR	60
Table 9-1	Equipment Required for Different UNAVCOM Services	68

1.0 INTRODUCTION

One of the most important air navigation aids today is the Secondary Surveillance Radar (SSR). Unfortunately, the cost and complexity of the full-scale radar of this type has prevented its application in all but the largest airports and heavily travelled airspace. However, a low-capacity version of such a radar can be developed to be used at small airports, mobile/shipborne air-traffic control systems, or in the remote Unattended NAVigation COMmunication (UNAVCOM) stations. In the latter service, the radar sends the detected information to a manned station by telephone lines or functions as a talkback SSR unit (TSSR), reporting the aircraft position back to the pilot, on the VHF radio.

The idea is feasible by elimination of the SSR sophisticated tracking features and utilizing the merits of the popular inexpensive micro-computer technology.

The concept of low-traffic density SSR was identified by Canadian Astronautics Limited through carrying out design of a UNAVCOM station under a contract from Transportation Development Centre (TDC), Transport Canada [1]. It seems feasible to develop such a radar selling for under $150,000, thus making it affordable for small airports.

The proposed system consists of the Antenna Unit, basic SSR Interrogator, Data Acquisition Unit, Power Supply and one or more of the Display/Report options discussed in the next paragraph. The equipment is housed in a standard 19" rack and is of a modular construction for ease of maintance and service (Figure 1).

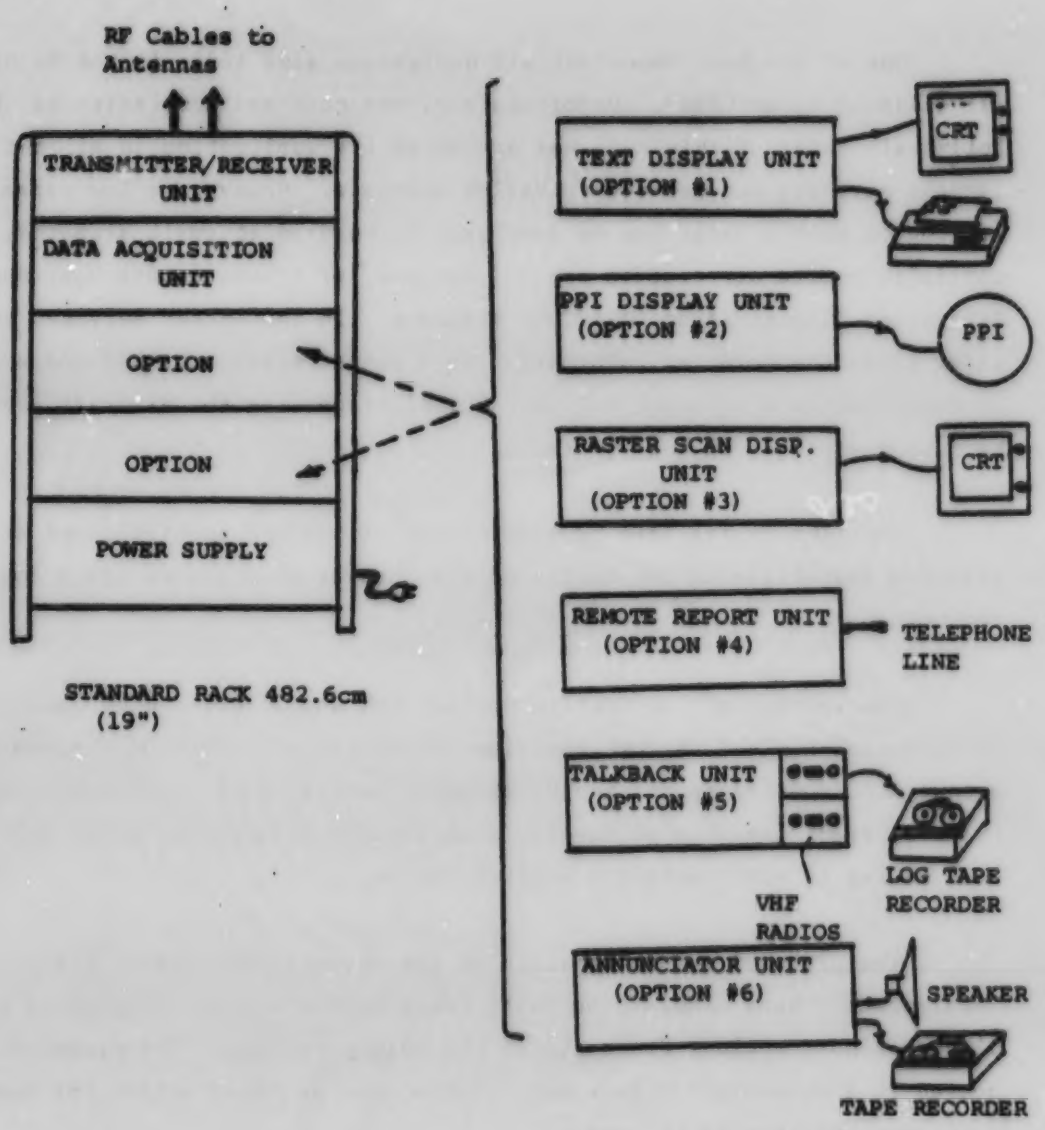


FIGURE 1 LOW-CAPACITY SSR FAMILY EQUIPMENT

The display/report options are as follows:

1) Text Display Option: It presents the aircraft identification and position in the form of a line text on a CRT monitor or records them on a line printer.
2) PPI Display Option: The information is displayed on a Plan Position Indicator (PPI).
3) Raster Scan Display Option: The infromation is presented in a format similar to PPI, however, it is outputted to an ordinary TV monitor in the raster scan form.
4) Remote Reporting Option: The radar findings are sent, by a modem, to a manned control centre by a telephone line. A display unit outputs the radar detection in the control centre.
5) Annunciator Option: The radar findings are voice announced on a speaker. Therefore, the air-traffic controllers could listen to it while performing other tasks in the station.
6) Talkback Option: The aircraft identification and its position are reported, with synthesized voice, back to the pilot through the aircraft VHF radio. This is the proposed version of the SSR for UNAVCOM stations intended for installations in the remote Arctic regions.

2.0 USER'S VIEW OF THE LOW-CAPACITY SSR

The proposed SSR system can be used in many different modes, depending on the option(s) installed on it. Some of these application modes are described below:

2.1 AS A NAVIGATION AID AT SMALL AIRPORTS

The system can be installed in low-traffic airports as a navigation aid for the air-traffic controllers. In this mode the different display options shown in Figure 1 and different printers or recorders could be used for traffic logging.

Activation of the Special Purpose Identification Switch (SPI), by the pilot, is not necessary for the display of aircraft position on the operator screen. However, SPI switch could be used, in its usual sense, to make the aircraft distinct from the others, on the display, for whatever reason which may pertain.

Further, the radar could be installed in the control room or remotely in the air field and forward the display information by a modem on telephone lines or other communication means.

2.2 A COMPONENT IN CENTRALIZED AIR-TRAFFIC MONITORING SYSTEM

Several unattended low-capacity SSRs can be installed, to cover a large air space, each sending display information to a manned control and monitoring centre. The display information in these radars is sent by modems on the telephone lines or other communication media.

2.3 AS A TALKING AND ANNUNCIATOR RADAR

In this mode, the radar is installed in an airport or flight control room and functions as a talking or annunciator unit, reporting aircraft in the range by words. The air-traffic controllers could listen to the report while performing other tasks in the station, which relieves them from constantly looking at the CRT displays.

The unit could be programmed to either announce all the aircraft in the field or only those activating the SPI switch.

2.4 AS A TALKBACK RADAR (TSSR)

In this mode, the radar sends the aircraft Identification and position information, back to the pilot, by aircraft VHF radio. The report is in the form of synthesized voice. Such communication with the pilot could also be sent by phone line, terrestrial or satellite link to a manned traffic control centre for monitoring.

Further, the communication with the pilot could be logged on a tape recorder along with time and date, which is also generated by the same voice synthesizer and appended to the message.

This mode of operation is the one proposed for application in the UNAVCOM stations, proposed for use in Canadian Arctic regions.

It is important to note for this operation, the activation of SPI switch is necessary, as a request for service, to initiate the report. The sequence of events is as follows:

- The pilot requesting the service activates the transponder SPI switch.

- TSSR of the UNAVCOM station replies. with synthesized voice, on the VHF radio:

  "AIRCRAFT SQUAWKING CODE ONE TWO THREE FOUR YOUR POSITION IS RADIAL ONE FIVE ZERO AT ZERO FIVE MILES FROM XYZ STATION."

- In the case of any fault detection in the SSR, the system would inform the pilot by reporting:

  "THIS IS XYZ STATION, SSR UNIT NOT FUNCTIONAL, RELY ON NDB ONLY."

Further, in the case of more than one aircraft in the TSSR range, only the aircraft depressing the SPI switch would be serviced. However, if more than one aircraft are activating this switch the situation would become confusing. Three operational procedures to avoid this confusion are proposed as follows:

2.4.1 RADIO LOG-IN PROCEDURE

The aircraft approaching the station, radios his identification, by the type and call sign of his aircraft [2]. The TSSR plays back the message followed by a synthesized voice message requesting the pilot to squawk by a certain transponder code. The pilot upon entering this code would be distinguished from other aircraft since other aircraft logging in receive different identification codes from the TSSR. The pilot upon leaving the TSSR range, turns the transponder off or changes his code to standard 1200 code and the TSSR computer drops him off the list of aircraft in the field. The sequence is as follows:

- The pilot radios:

  "CESSNA, 152 SKYHAWK, ALPHA BRAVO CHARLIE."

- The station upon receiving this radio message radios back.
- "CESSNA, 152 SKYHAWK SQUAWK 1207."
- When 1207 is selected, note that this aircraft is the 7th in the list of aircraft entering the field. The station immediately after detecting the aircraft, by SSR, radios back:

  "AIRCRAFT SQUAWKING 1207 YOU ARE LOGGED IN, YOUR POSITION IS RADIAL ONE FIVE ZERO AT ZERO FIVE MILES FROM XYZ STATION."

The pilot keeps on listening to his radio for traffic guides and knows about the position of other aircraft. He can press the SPI switch if he wants to update his position information. He should change back to 1200 code upon realizing he has left the radar range, thus dropping himself off the list of aircraft being serviced. The assigned code (i.e. 1207) should not be used for other aircraft, for few minutes, to make sure radar confusion does not occur.

COMMENTS:

This procedure requires that the pilot know that he is in the vicinity of a radar station. Therefore, it does not comply with the philosophy of UNAVCOM stations because pilots attempting to use the service do not know whether they are in the vicinity of a radar.

On the other hand, the procedure is excellent for unattended airports (Ref. 2) where the purpose of the TSSR is to give the pilots landing and take-off instructions rather than enroute position information.

Moreover, the complexity of the handshake radio communication makes the station computer grow too sophisticated for the purpose.

2.4.2 CODE ASSIGNMENT WITH THE FLIGHT PLAN

In this procedure, the pilots flying in areas of the country where UNAVCOM stations are installed are assigned a transponder identification code upon submission of their flight plan. By this method each aircraft in the range has a different transponder code and receives position reports of all aircraft, asking for service.

COMMENTS:

The procedure is excellent in terms of UNAVCOM station operation. However, it imposes extra administration of flight plans and transponder identification code numbers. Also, the service is restricted for pilots intending to fly to the UNAVCOM region and is not available for aircraft being lost or accidentally entering the region. For such an aircraft the service is still available. Confusion arises if two aircraft of such type enter the region and simultaneously request service.

2.4.3 TSSR WARNING PILOTS TO CO-OPERATE

In this method the TSSR, upon detection of more than one aircraft asking for service, radios the following message:

"MORE THAN ONE AIRCRAFT ASKING FOR SERVICE.
ACTIVATE SPI SWITCH AGAIN"

The pilots, upon receiving such a warning, could communicate with each other on the VHF radio and resolve the situation so as to receive the service from the station, one by one, by depressing the SPI switch one at a time, or by dialing different numbers on their transponders.

COMMENTS:

The method seems to be the most practical arrangement without complicating either the flight administration or the UNAVCOM station equipment.

There seems to be some inherent confusion among the pilots involved with such a situation. However, the problem is no more complicated than deciding who to talk to on a two way radio. Secondly, the probability of having two pilots entering the range of TSSR and simulanteously asking for service is so low that the implementation of this method is best from both the economic and the performance points of view.

3.0 SYSTEM DESIGN DESCRIPTION

The proposed system consists of the following units.

- Antenna Unit: which consists of a monopulse directional antenna or a combination of a directional and an omni-directional antenna.
- Interrogator Unit: It generates the interrogation pulses and sends them to the antenna unit. Also, it receives the transponder response pulse, reshapes them and outputs them to the data acquisition unit.
- Data Aquisition Unit: This unit obtains the aircraft identification, range, azimuth and altitude from the reshaped video signal inputted from the interrogator unit. This information is outputted to the display or report units.
- Display/Report Options: These units convert the aircraft information from the data acquisition unit into the usable forms such as CRT display, synthesized voice announcement, remote modem data communication, and talkback radio report. Traffic logging on printers or tape recorders is also provided.

Each of the above units are described, in detail, as follows:

3.1 ANTENNA UNIT

Two different approaches could be taken to realize the antenna, as follows:

3.1.1 E-SCAN ANTENNA

This antenna has no rotating or moving part. Therefore, it seems to be ideal for UNAVCOM applications. It consists of a circular array of dipoles with electronically controlled phase difference between them [3]. The phase differences could be controlled in a way that the antenna forms a beam with the desired beamwidth and direction. The antenna could be a Monopulse unit or designed to work with an omni-directional antenna.

The only drawback of such an antenna is its extremely high cost. However, considering the maintenance cost of a mechanically moving antenna, in a UNAVCOM station, it may pay back in the long run. A conceptual design of such an antenna is presented in Figure 2. It is cost estimated in Section 4.

3.1.2 M-SCAN ANTENNA

This antenna consists of a rotating directional antenna, roto-feed mechanism, radome and an omnidirectional antenna (if the directional antenna is not monopulse).

The directional antenna conceptually is a broad-side dipole array with 12 elements [4] and with half-wave length dipole spacing, as shown in Figure 3. The approximate characteristics are:

Gain = 50 (absolute)
Elevation beamwidth = 55°
Azimuth beamwidth = 10°

The roto-feed mechanism consists of a coaxial inductive joint and an unbalanced-to-balanced transformer to feed the dipoles after the joint.

The antenna rotates at a rate of 10 Revolutions Per Minute (RPM) by means of a motor-gear mechanism which is oiled and sealed to work for a long time (one year) without maintenance.

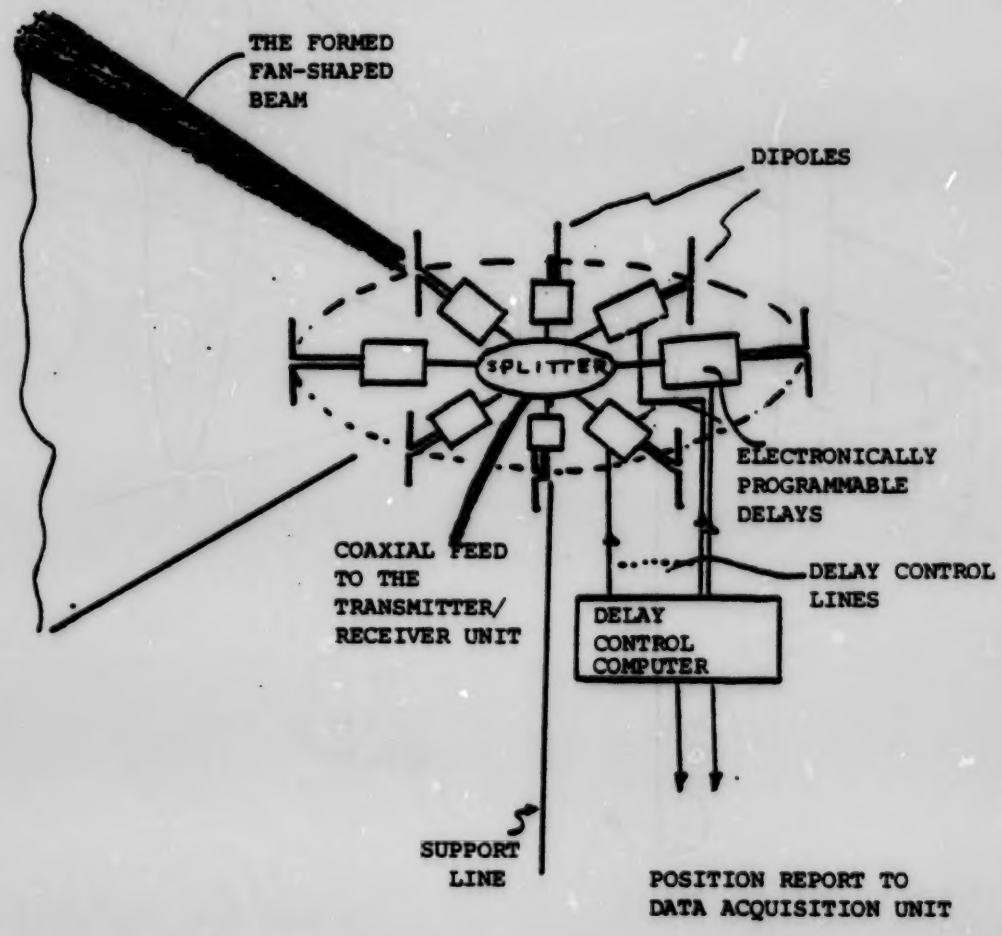


FIGURE 2 DESIGN CONCEPT OF THE E-SCAN DIRECTIONAL ANTENNA

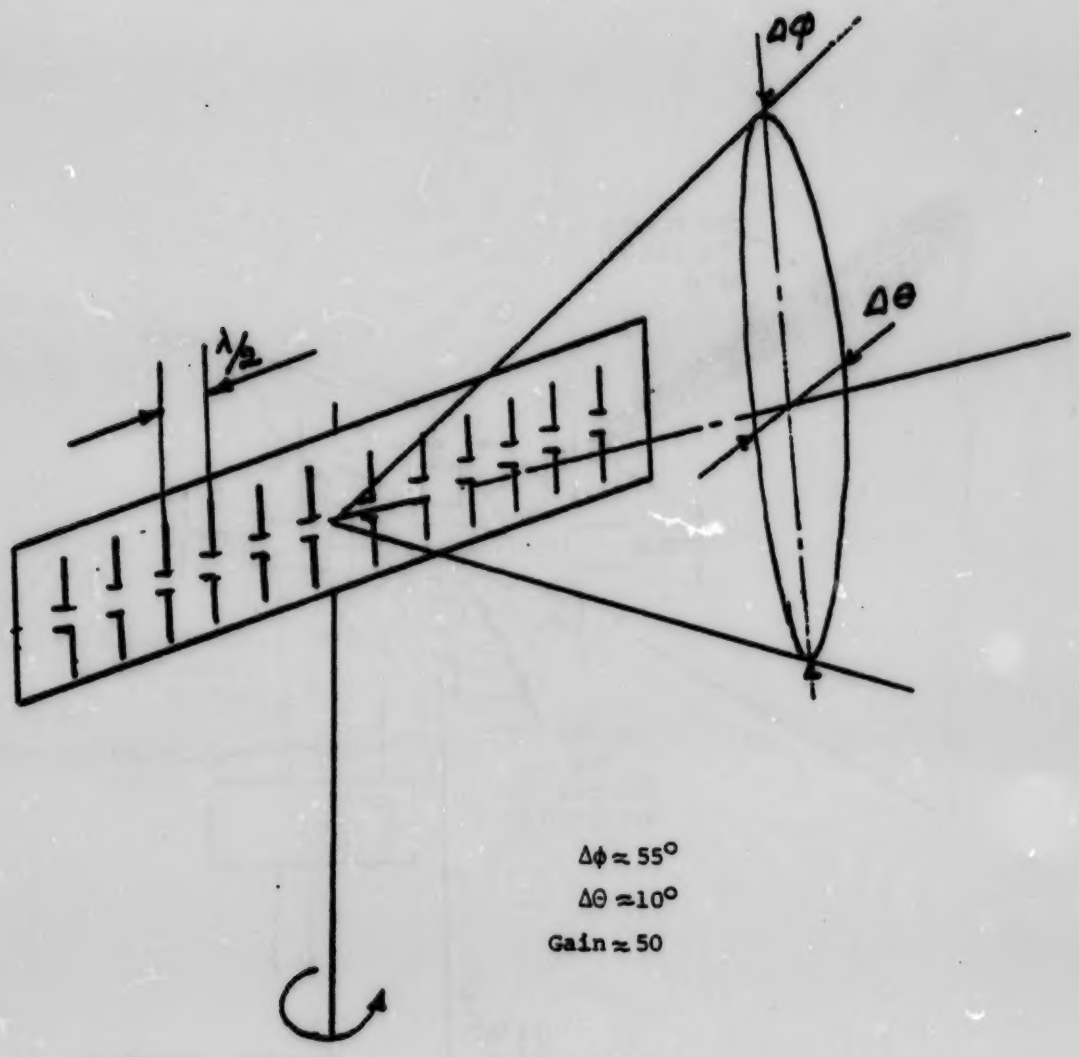


FIGURE 3 DESIGN CONCEPT OF THE M-SCAN DIRECTIONAL ANTENNA

The antenna could be housed inside a cylindrical fiberglass or plastic radome. Such an arrangement is recommended for areas with a harsh weather environment.

An omni-directional antenna of two vertically stacked dipoles is recommended for use with non-monopulse directional antenna.

3.2 INTERROGATOR UNIT

This unit is block-diagrammed in Figure 4 and it consists of the following:

- Coder Module: To generate the SSR interrogation ($P_1P_2P_3$) pulses.
- Transmitter: To modulate the above pulses to 1030 MHz RF and amplify the power for transmission to the aircraft.
- Receiver: To receive the transponder, 1090 MHz, pulses and output video pulses.
- Video Processor: To shape the wide-dynamic-range video output of the receiver, and to reject parasitic spikes by pulse width discrimination.
- Fault Detector Module: To monitor SSR for operational faults and report the status to data acquisition unit.

Each of these subunits is detailed below:

3.2.1 CODER MODULE

The module is block-diagrammed in Figure 5. It is basically a pulse generator, producing $P_1P_2P_3$ pulse group, with group repetition rate (PRF) of 150 to 450 Hz adjustable. It also generates transmitter Side Lobe Suppression (SLS) switch control pulse and the interrogation tag pulses for the data acquisiton unit.

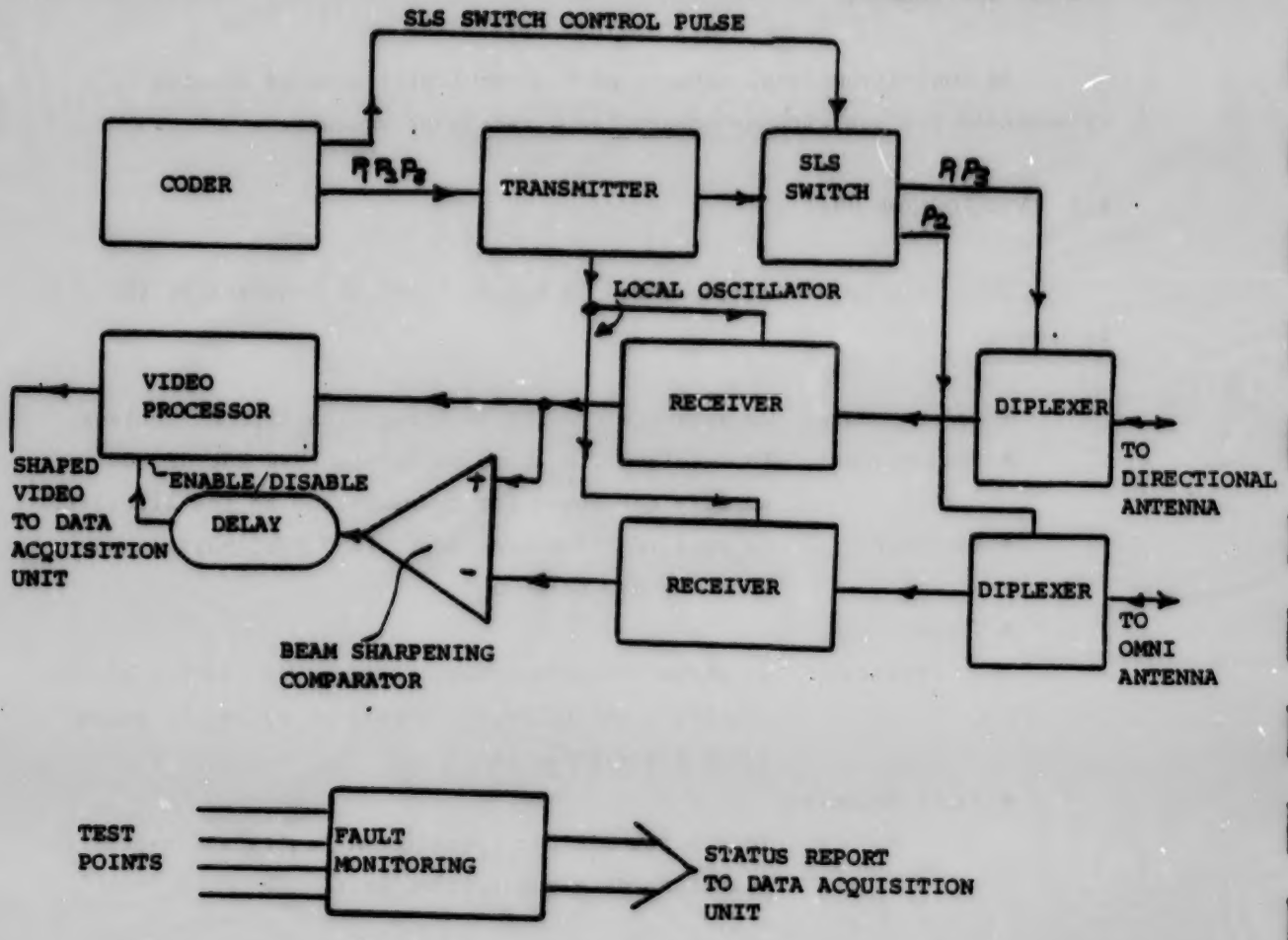


FIGURE 4 BLOCK-DIAGRAM OF THE INTERROGATOR UNIT

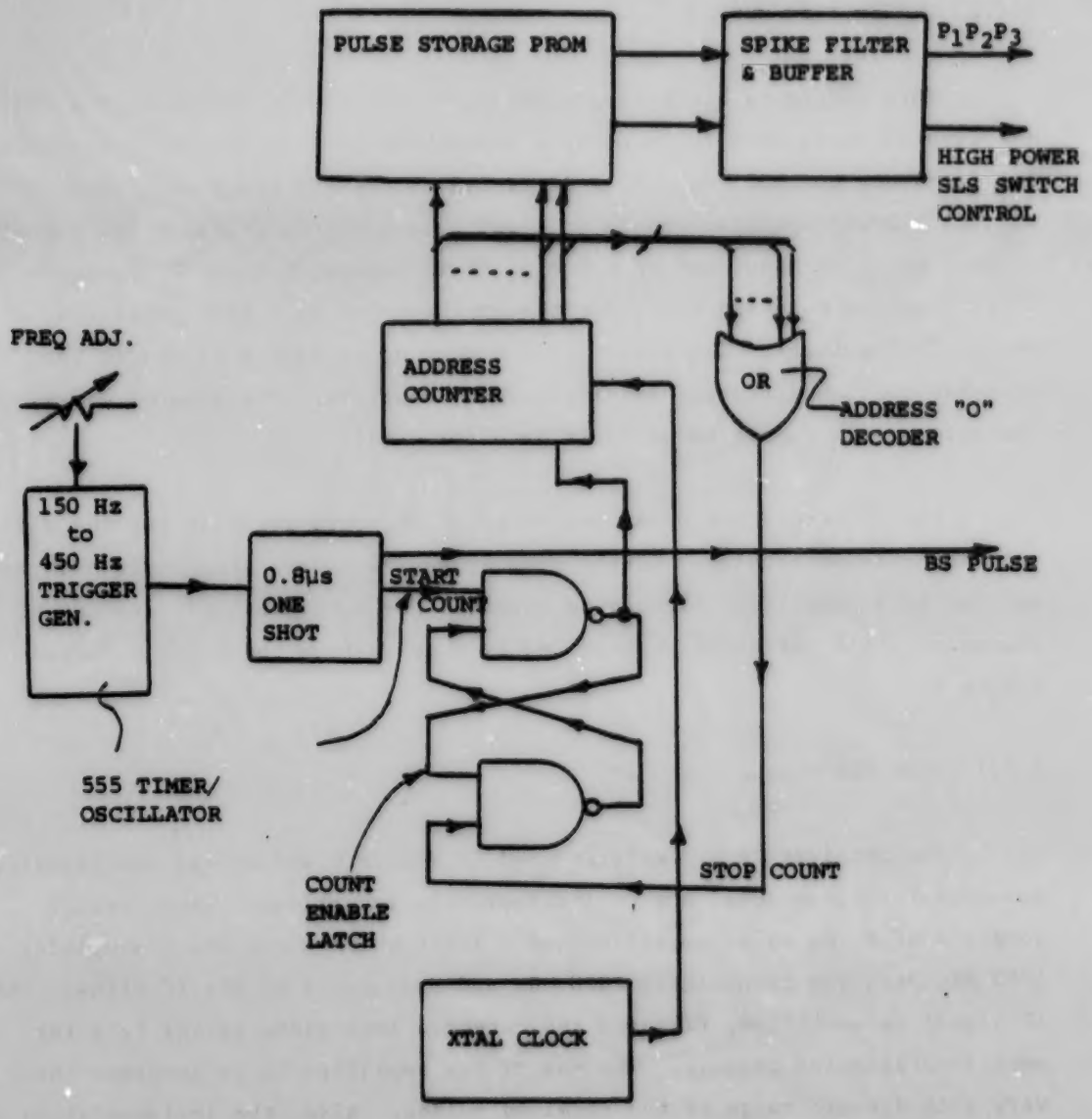


FIGURE 5 BLOCK-DIAGRAM OF THE COUNTER MODULE

The pulses are stored in a PROM and are generated at the data output of the PROM by sweeping across the PROM address range, once per every trigger of the PRF Generator.

The module should be implemented with Low Power Schottky TTL (LS-TTL).

3.2.2 TRANSMITTER MODULE

This module is block-diagrammed in Figure 6. It consists of a 103.0 MHz crystal oscillator followed by a Phase-Lock Loop multiplier which brings the frequency to 1030 MHz. This RF is fed to the PIN diode modulator through a 3-way splitter and is followed by a harmonic filter. The output at this point is modulated by $P_1P_2P_3$. It is separated to RF P_1 P_3 for directional antenna and to P_2 for the omni antenna by a high power PIN switch (SLS switch). The output of the high power switch is fed to the antennas through diplexers and directional couplers. The flow of energy to the antennas is monitored by fault detector module.

The PIN diode SLS power switch is an economic solution for the side-lobe suppression problem. In the more expensive radars athe whole modulator and the power amplifier circuit is repeated for both omni and directional channels. This circuit is controlled by a pulse from the Coder module, Figure 7.

3.2.3 RECEIVER MODULE

The receiver is block-diagrammed in Figure 8 and it has two identical channels for directional and omni-directional receptions. Each channel consists of a low noise amplifier and a mixer which mixes the transponder 1090 MHz with the transmitter 1030 MHz and produces a 60 MHz IF signal. the IF signal is amplified, filtered and detected into video pulses by a log amplifier/detector circuit. The use of log amplifier is to compress the very wide dynamic range of the received pulses. Also, the implementation of a Sensitivity Time Control (STC) feature, according to $\frac{1}{R^2}$ Law, may be simplified to the addition of a ramp function, in the Log amplifier.

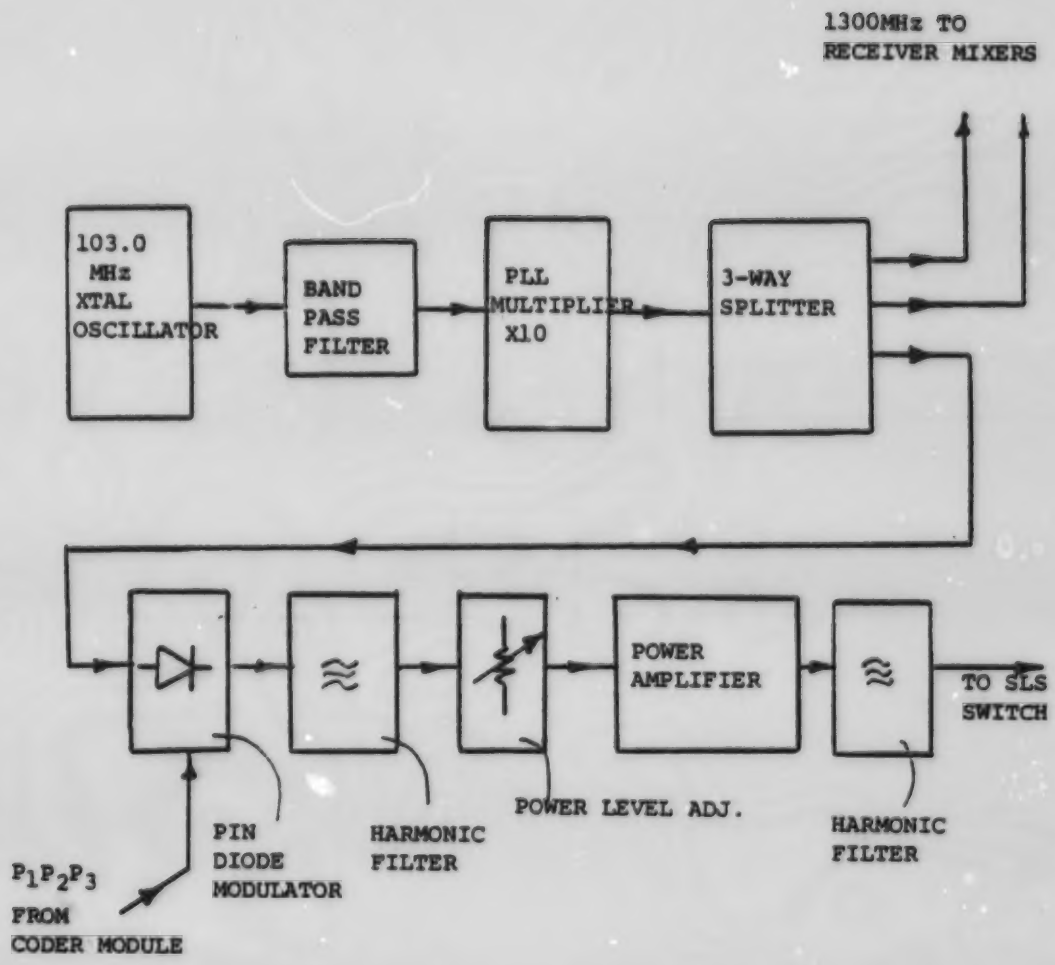


FIGURE 6 CONCEPTUAL DESIGN OF THE TRANSMITTER

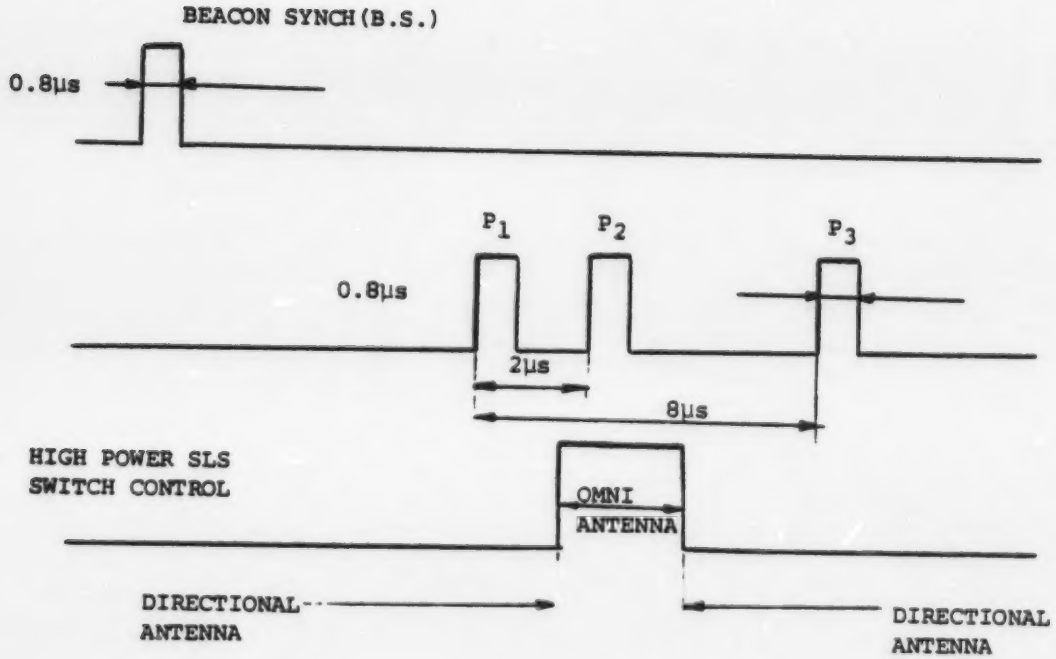


FIGURE 7 SSR PULSE TIMING DIAGRAM

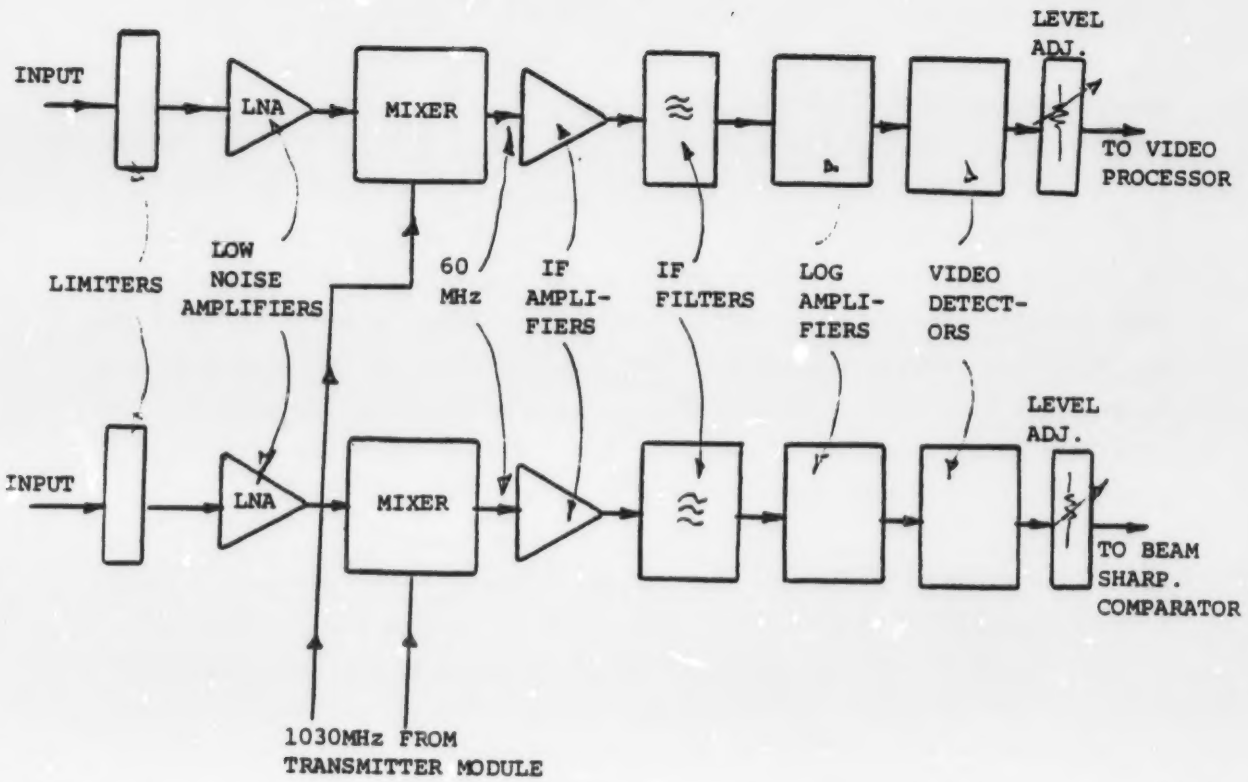


FIGURE 8 CONCEPTUAL DESIGN OF THE REVEIVER

The detected video in the directional and omni channels are properly scaled by the "level Adjust" and compared to each other. Further processing of the video pulses will be disabled if the video from the directional channel is not larger than the video from the omni channel. This is called Receiver Side Lobe Supression (RSLS) and is used to sharpen the beam of the directional antenna. The video of the omni channel should be delayed to compensate for the video processor internal delay.

3.2.4 VIDEO PROCESSOR

This module shapes the video pulses, having a very wide amplitude and dynamic range, to TTL level. It also rejects pulses having less than 300 ns width.

A block diagram of the module is presented in Figure 9. The shaping of the video pulses is based on widening the input pulse by 50 nse two times repetitively. The output is added to the input pulse in order to widen it. The amplitude is then divided by 2 and compared with the 50 ns delayed pulse. The net result of the process is to compare the pulse with a threshold level equal to its own half amplitude. A TTL pulse with half amplitude width of the original pulse is, therefore, produced.

The spike rejection is provided by firing a 300 ns one shot with the Reading edge of the video pulse. The output of the one shot blocks the passage of the video pulse through a gate. Therefore, only video pulses with width of less than 300 ns are eliminated. The pulses passing through are width adjusted to 450 ns by a second one shot.

3.2.5 FAULT MONITORING

This circuit monitors the SSR, detects the operational faults and reports them to the data acquisition unit.

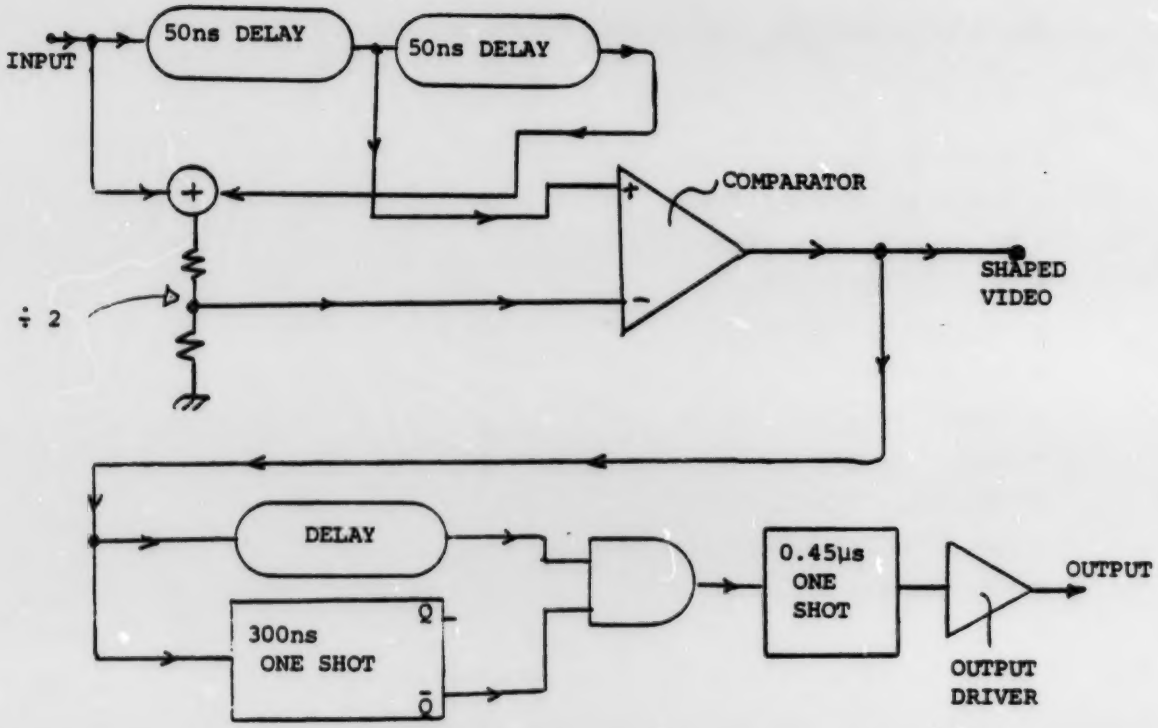


FIGURE 9 CONCEPTUAL DESIGN OF THE VIDEO PROCESSOR

The function monitored are as follows:

1) Interrogation pulse width.
2) Interrogation mode timing.
3) Transmitter output power.
4) Transmitter output VSWR.
5) Receiver sensitivity fault.

The module is implemented by LS-TTL timer/counters.

3.3 DATA ACQUISITION UNIT

The unit is presented in Figure 10. It consists of the following blocks:

- Frame decoder
- Garble rejection filter
- Response shift register
- Response multiplexer
- Response registers
- SPI decoder
- Range decoder
- Azimuth decoder
- SSR status report port
- Handshake and supervisory circuit
- Code processor circuit

Each of these functional blocks are described below:

3.3.1 FRAME DECODER

Each response of the transponder is marked by two framing pulses F_1 and F_2. The detection of this pulse pair is an indication of a response and can be used to strobe the interrupt signal to trigger the decoding of the response.

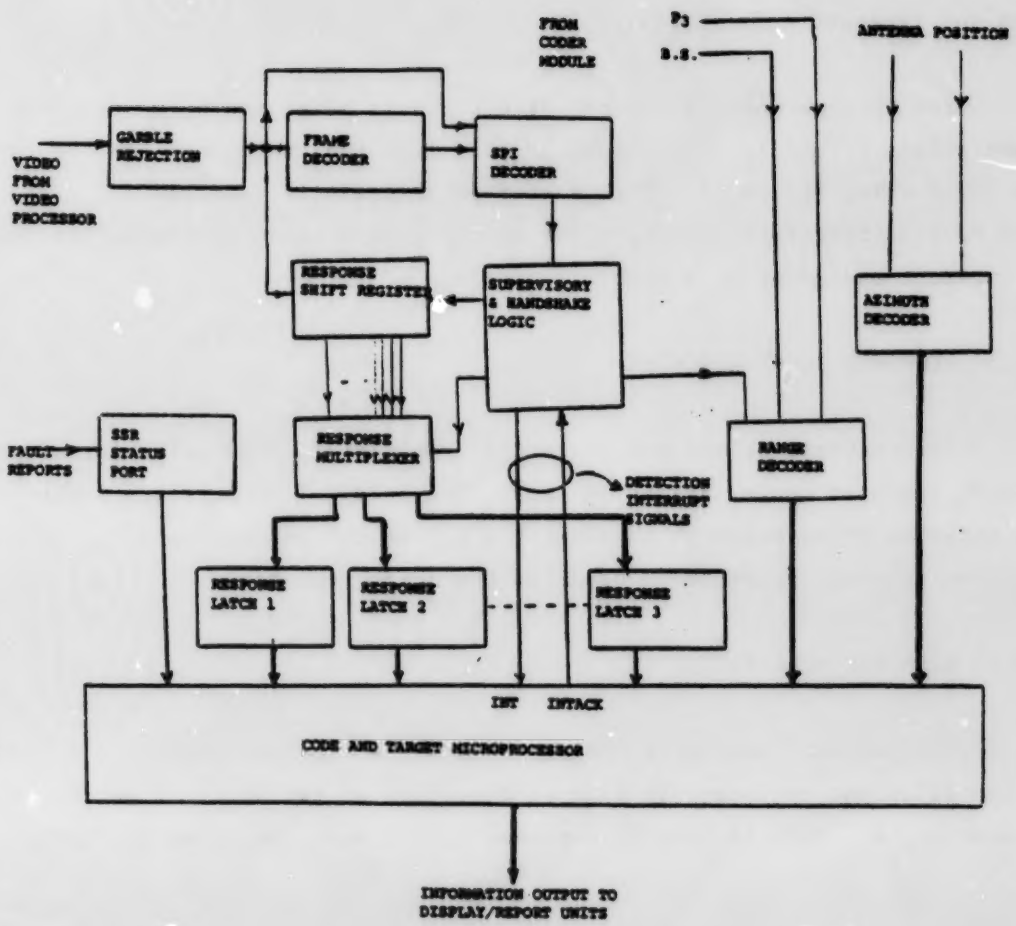


FIGURE 10 BLOCK-DIAGRAM OF THE DATA ACQUISITION UNIT

The frame decoder detects the arrival of F_1 F_2 pulses by delaying F_1 and ANDing it with F_2. A pulse width discriminator is also needed after the AND gate to accept at least 300 ns of overlap between delayed F_1 and F_2.

3.3.2 GARBLE REJECTION FILTER

The response pulses of two aircraft, within the beamwidth of the same azimuth angle, could overlap in such a manner that the responses could not be separated, Figure 11. such a situation should be rejected so that it does not generate a false display or report.

For this purpose, a raster pulse train is generated by passing the frame pulses F_1 and F_2 down a tapped delay line and the outputs of the taps are logic ORed, Figure 12. This raster pulse train is inverted and ANDed with F_2 (4), therefore, the F_2 pulse in the garble case, is blocked to cause an interupt and generate a report.

3.3.3 RESPONSE SHIFT REGISTER

The response pulses are converted from serial to parallel format, by a shift register chain, having 14 taps. The parallel outputs are latched by the detected frame pulse which marks the end of the response and the time that the response pulse train occupies the shift register.

3.3.4 RESPONSE MULTIPLEXER

The parallel output of the response shift register should be routed to two different registers in case of detection of two aircraft on the same azimuth angle. This is done by response multiplexer, as shown in Figure 10.

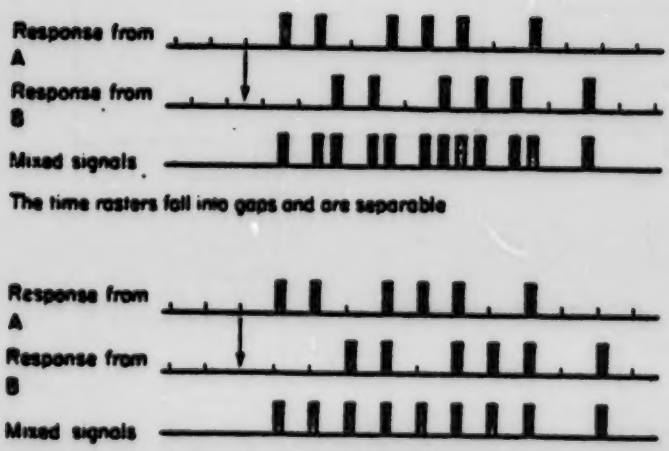

Response from A
Response from B
Mixed signals
The time rasters fall into gaps and are separable
Response from A
Response from B
Mixed signals
The time rasters partially coincide so that the responses produce a new false code which must be suppressed

FIGURE 11 PULSE TIMING DIAGRAM OF GARBLE [4]

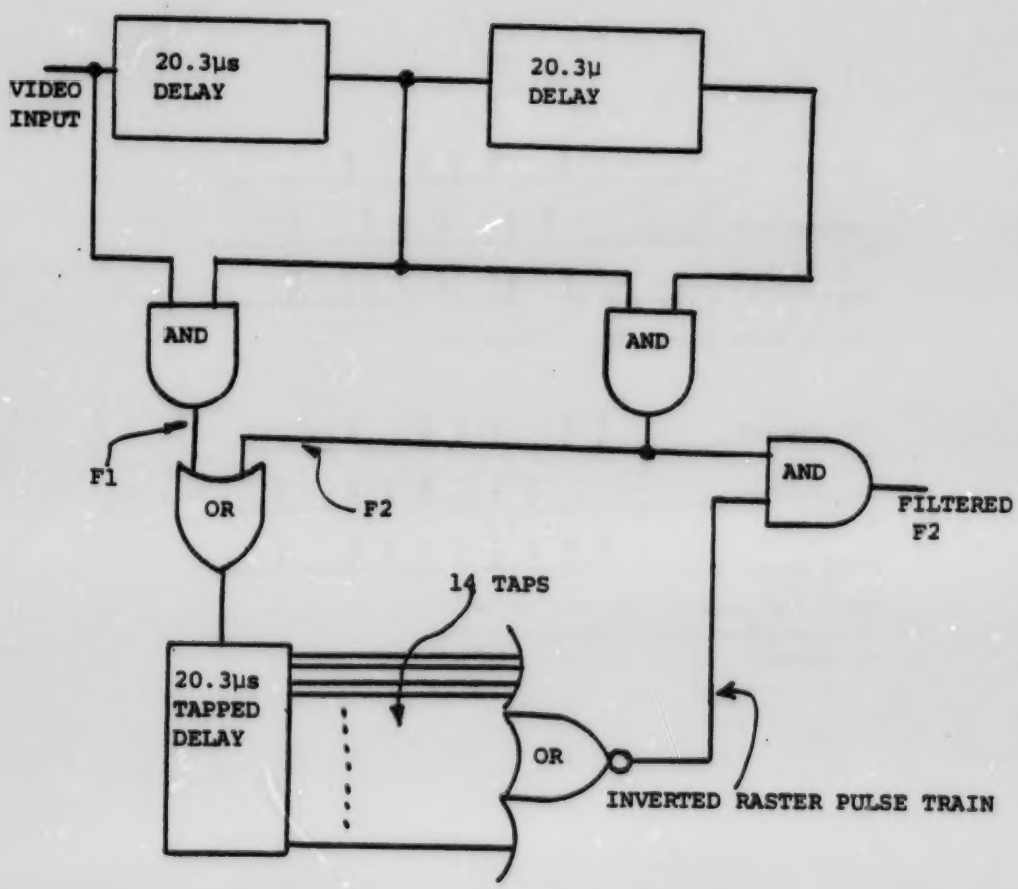


FIGURE 12 CONCEPTUAL DESIGN OF A GARBLE FILTER

3.3.5 RESPONSE REGISTERS

The response code, out of the response shift register and multiplexer, should be latched until it is read by the code processing microprocessor. This is done by the response latching registers which are controlled by the handshake and supervisory logic.

3.3.6 SPI DECODER

The existance of the Special Purpose Identification (SPI) pulse, is detected by this decoder. For this purpose the detected frame pulse is delayed for 4.35 μs and logically ANDed with the response pulse train. A pulse width discrimination, after rhe AND gate, is necessary to eliminat pulse timing errors of more than 0.1 μs.

3.3.7 RANGE DECODER

The aircraft range is derived from timing between P_3 pulse (Interrogation) to the decoded frame pulse (Response). This is done by the Range decoder circuit which is a timer/counter started by P_3 and stopped by the frame pulse. The counter, after being stopped, transfers the count to a register which is read by the micro-processor. It continues to count for the range detection of a possible second aircraft on the same azimuth angle. The counter is cleared by the Beacon Synch pulse.

3.3.8 AZIMUTH DECODER

The azimuth position of the aircraft is determined by noting the angular position of the antenna with respect to North reference. The position of the antenna is reported by the antenna pedestal, to the data acquisition unit, by the two pulses, Antenna Reference Pulse (ARP) and Antenna Change Pulse (ACP).

A counter circuit is used as the azimuth decoder. This counter is cleared by ARP and counts the number of ACP pulses thereafter. The result is read by the microprocessor upon being interupted by the frame pulse.

3.3.9 SSR STATUS REPORT PORT

The possible SSR faults, if detected by the fault monitoring module, are reported via this port to the display/report microcomputers.

3.3.10 HANDSHAKE AND SUPERVISORY LOGIC

This circuit generates the strobe signals for latching the code pulses, controls the response multiplexers, time/counters, and generates the interupt for the microprocessor which decodes the response.

The sequence of the process is as follows:

The detection of frame pulse results in latching the response code out of the shift register. This code is routed to the first register or the second if the detected frame pulses are first or second, respectively. At this time the resulting range and azimuth decoder counters are transferred to buffer registers to avoid reading wrong counts while counters are running. Then, an interrupt is generated to the microprocessor.

3.3.11 CODE PROCESSOR CIRCUIT

The detected code from the aircraft transponder, and the corresponding range, azimuth, and SSR status readings are passed to this processor.

This circuit, which is a microprocessor, stores the radar reports and forms the transponder code, altitude (for mode C interrogation), range and azimuth of the aircraft and outputs them to the display/report units. Invalid readouts are rejected by averaging (Integration).

The azimuth angle of the aircraft is estimated by this processor to be the mid-point between the first and last detection of the aircraft.

The received signal is interpreted, by the processor, as the transponder code if mode 3A is interrogated and as the aircraft altitude if mode C is interrogated.

Further, the outputting of the aircraft information to the display/report units is prohibited if an SSR fault is read by the processor from the SSR status port. An indication of SSR operational fault is forwarded to the display/report units, instead.

3.3.12 THE IMPLEMENTATION OF THE DATA ACQUISITION UNIT

Figure 10 shows the data acquisition unit in terms of functional blocks. Some of these functional blocks can be implemented by a single circuit module, for example, the same shift register used as the delay line for the frame decoder can also be used for serial to parallel conversion of the response code. Also, the frame decoder and garble rejection filter are merged together so that the second delay line of the garble filter works as the delay line for the frame decoder. Figure 13 shows the implementation of the data acquisition unit in terms of circuit modules as opposed to Figure 10 which presents the unit in terms of functional blocks.

3.3.13 SIMPLIFIED DATA ACQUISITION UNIT

In SSR installations for low density air-traffic areas, such as UNAVCOM, the garble rejection circuit could be eliminated. This provides considerable simplification of the unit since the response code multiplexer and the buffer registers could be eliminated, as well.

A system design of this type is presented in Figure 14. Here, one shift register is used both for frame decoder and response conversion to parallel format. The detected frame pulse is used to latch the response out of the shift register. It is also used to generate the interupt handshaking to pass the information to the code processor.

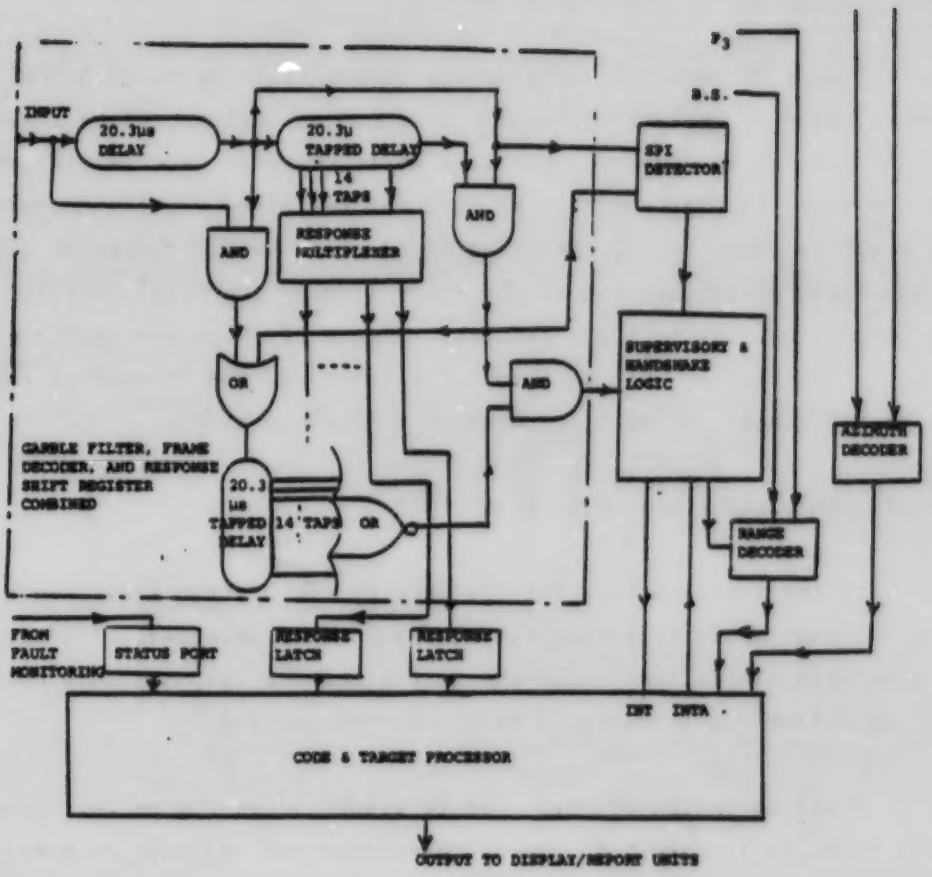


FIGURE 13 IMPLEMENTATION OF THE DATA ACQUISITION

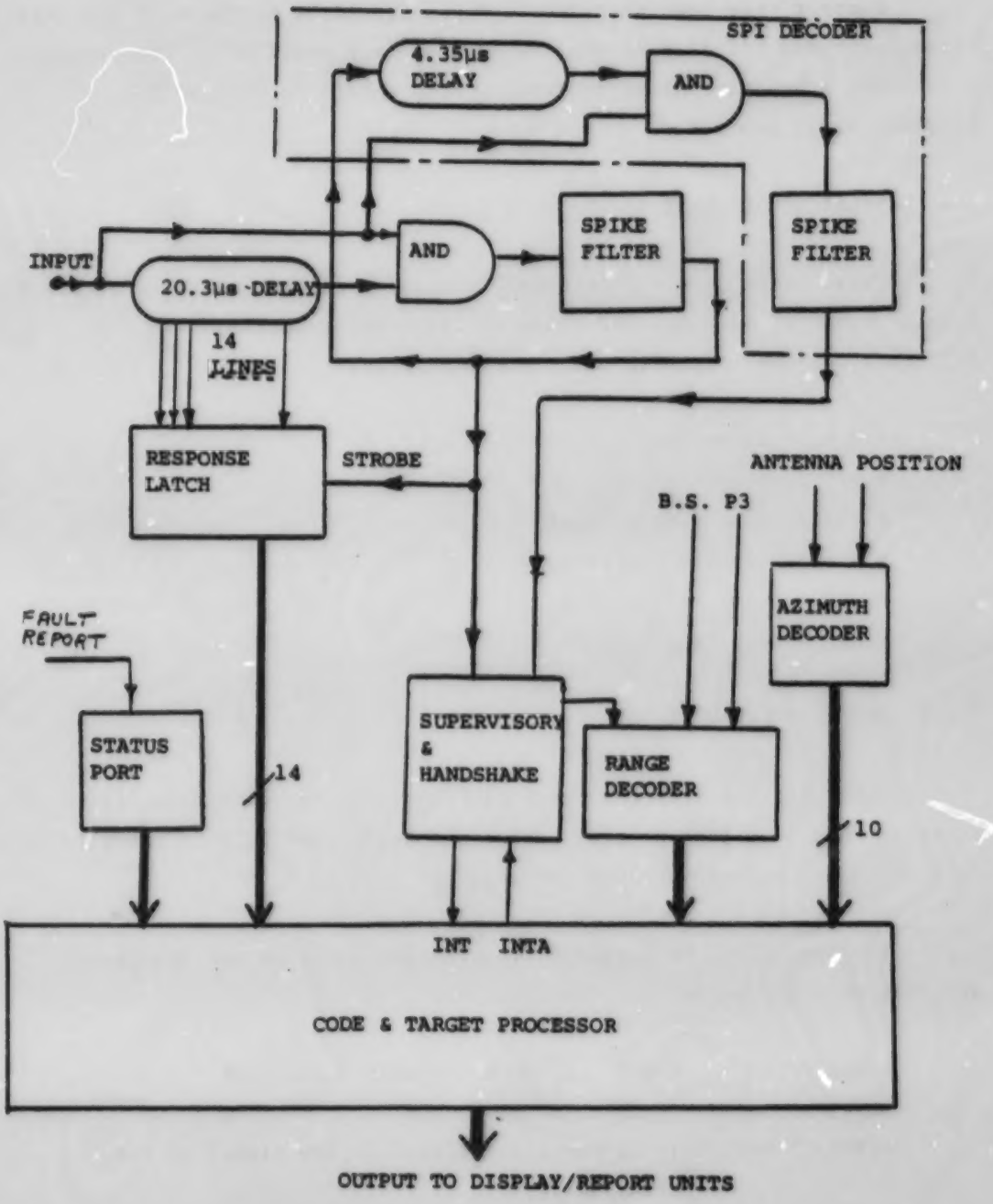


FIGURE 14 SIMPLIFIED DATA ACQUISITION UNIT

The range and azimuth circuits would remain the same as the circuit of Figure 13.

Further, the code processor computer could be merged with the display report processor if display requirements are not overloading the computer. Otherwise, a separate microprocessor system should be used as the display/report processor.

3.4 DISPLAY/REPORT UNITS

These units convert the radar findings into the usable information formats such as, displays and voice or data reports. The following different options for these units are identified:

- Text display unit
- PPI display unit
- Raster Scan display unit
- Remote display report unit
- Annunciator report unit
- Talkback unit

3.4.1 TEXT DISPLAY UNIT

This unit receives the radar findings from the data acquisition unit, converts them to a text display format and sends them to a CRT monitor as well as to an optional printer for logging.

The format of the displayed information would be one line per aircraft as shown below:

AIRCRAFT CODE RANGE AZIMUTH STATUS ALTITUDE

where:

AIRCRAFT CODE: it is the identification code dialed on the transponder.

RANGE	is the slant distance of the aircraft from the radar.
AZIMUTH	is the aircraft bearing angle with respect to the North reference.
STATUS	is a special code such as EMERGENCY, RADIO FAILURE, etc.
ALTITUDE	is the aircraft altitude as measured by the aircraft altimeter. This value is displayed if mode C is interrogated.

Further, displayed lines corresponding to aircraft with depressed SPI switch would flash. Display lines corresponding to aircraft sending emergency codes would also flash.

The unit is block-diagrammed in Figure 15. As seen, the unit is basically a microcomputer system which receives the radar findings from the data acquisition unit, forms the proper text and loads it to video memory and the line printer buffer. The stored text is later sent to the CRT monitor and the line printer by the display logic and the line printer interface circuit, respectively.

The CRT to be used with the unit would be a standard CRT monitor with composite NTSC video input signal, as specified in the proposed technical specifications.

The printer would be a small standard dot matrix line printer.

3.4.2 PPI DISPLAY UNIT

This unit presents the radar findings on a standard radar Plan Position Indicator, such as RCA AN/SPA4A. The display is a polar map of the area with aircraft marked as dots on the screen.

The unit is block-diagrammed if Figure 16, it consists of a microprocessor which converts the information obtained from the Data Acquisition unit to the form usable by a PPI display scope.

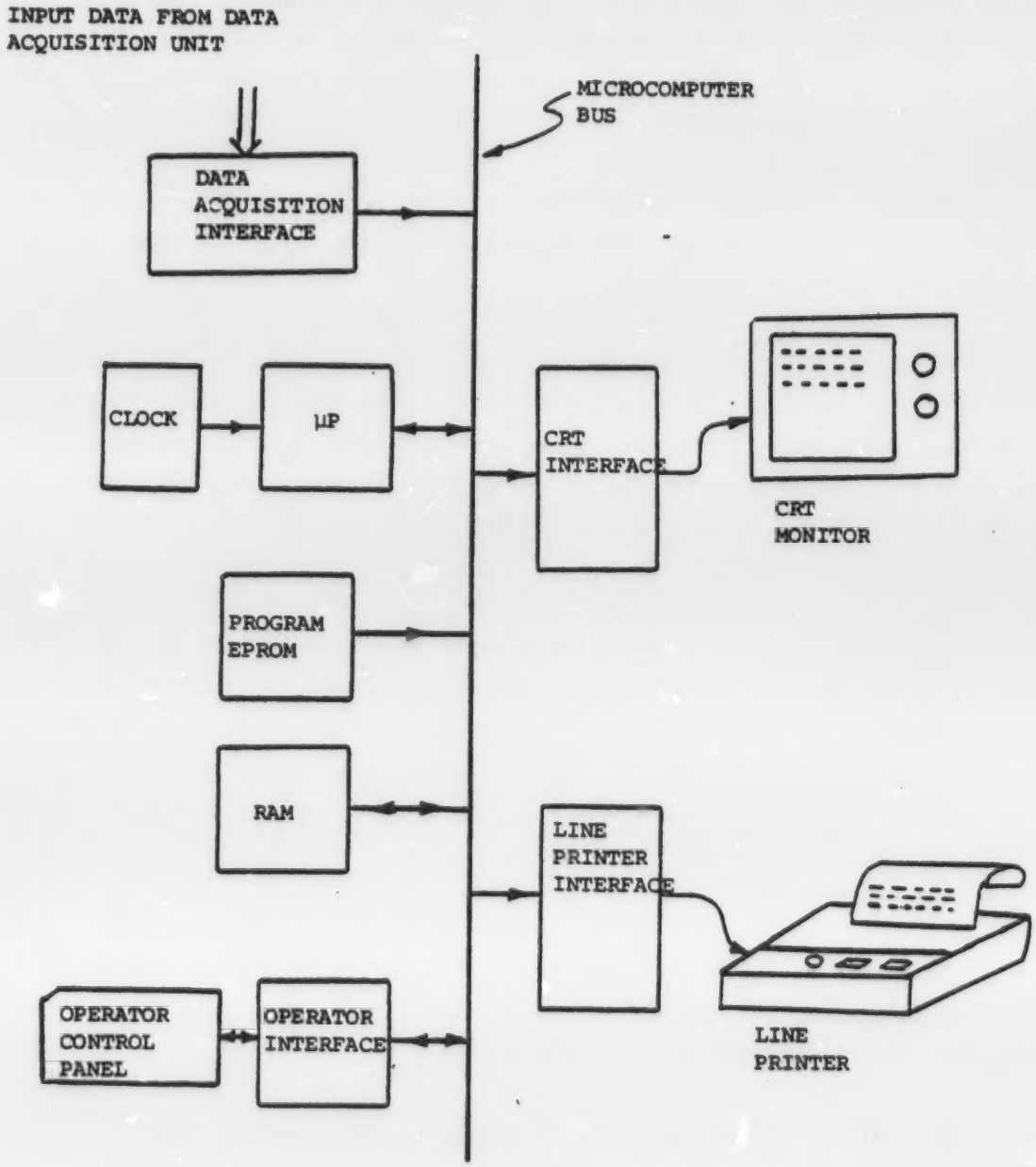


FIGURE 15 CONCEPTUAL DESIGN OF THE TEXT DISPLAY UNIT

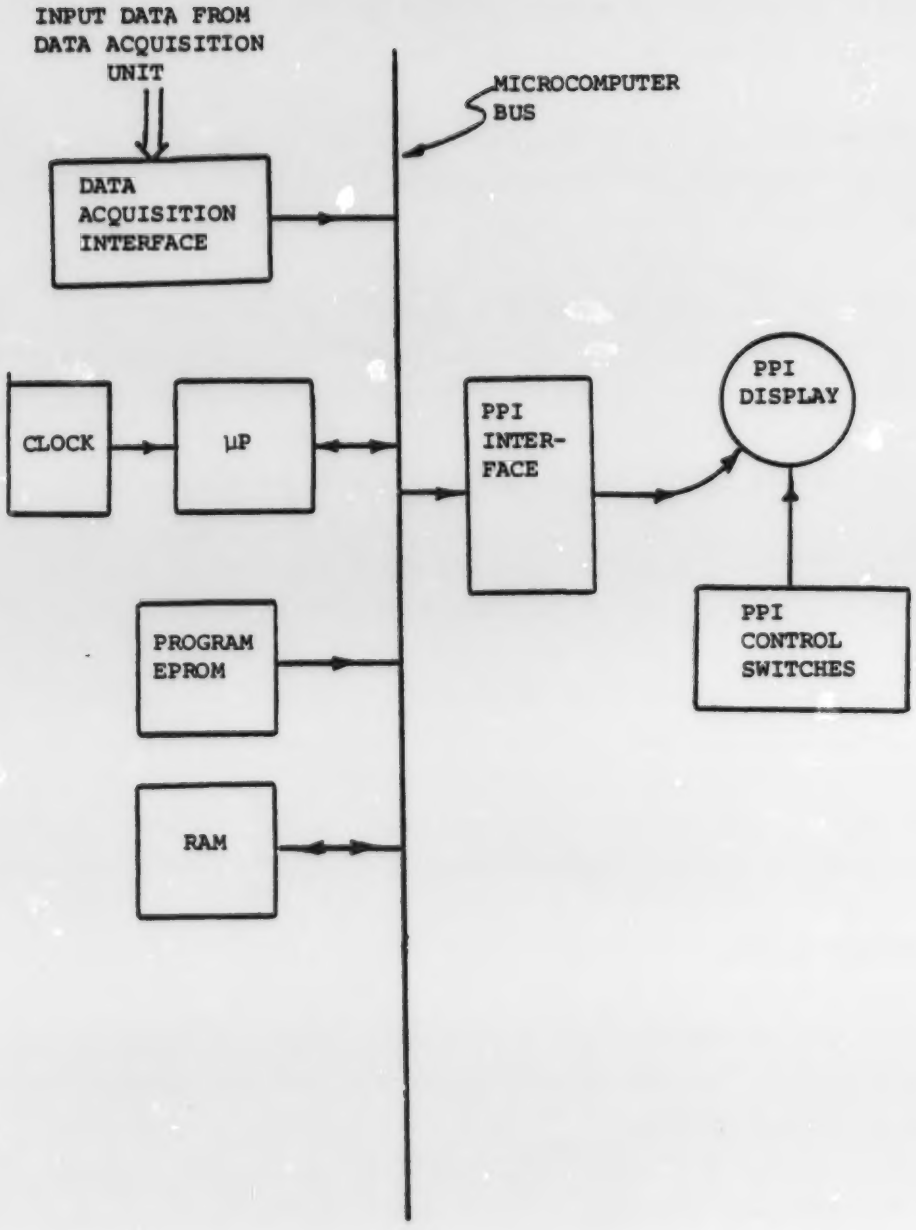


FIGURE 16 CONCEPTUAL DESIGN OF THE PPI DISPLAY UNIT

3.4.3 RASTER SCAN DISPLAY

This unit also generates a map-like display of the area, in fact, to the user it is very similar to PPI, except the rotating beam is missing. The display is on a TV CRT monitor instead of a standard radar PPI; therefore, it is lower in cost.

Further, since the display has stored the information in its memory, the change of the picture field and zooming is quite possible. This could be very helpful for the operators and the air-traffic controllers.

The unit is block-diagrammed in Figure 17. As seen, the microprocessor reads the information from the data acquisition unit and converts it into a map by a graphic program. The generated map is loaded into the memory. The video display logic sends this map to the CRT monitor by raster scanning of the desired portion of this memory.

The operator control switches allow the operator to select the display field, size and format or zooming of the picture.

The implementation of the unit would be with a popular MOS microprocessor system; however, the video memory and the display logic should be implemented with low-power Shottky TTL. This is because the display speed, according to the NTSC standard, requires memory acquisition speeds beyond the abilitiy of the MOS devices.

3.4.4 REMOTE DISPLAY REPORT UNIT

The findings could be sent to a remote location instead of being displayed locally. Any of the display options mentioned earlier could be used in the remote station.

This option is suitable for the remote unattended radars monitored by air-traffic centres or by the control tower where the radar is installed at an airfield.

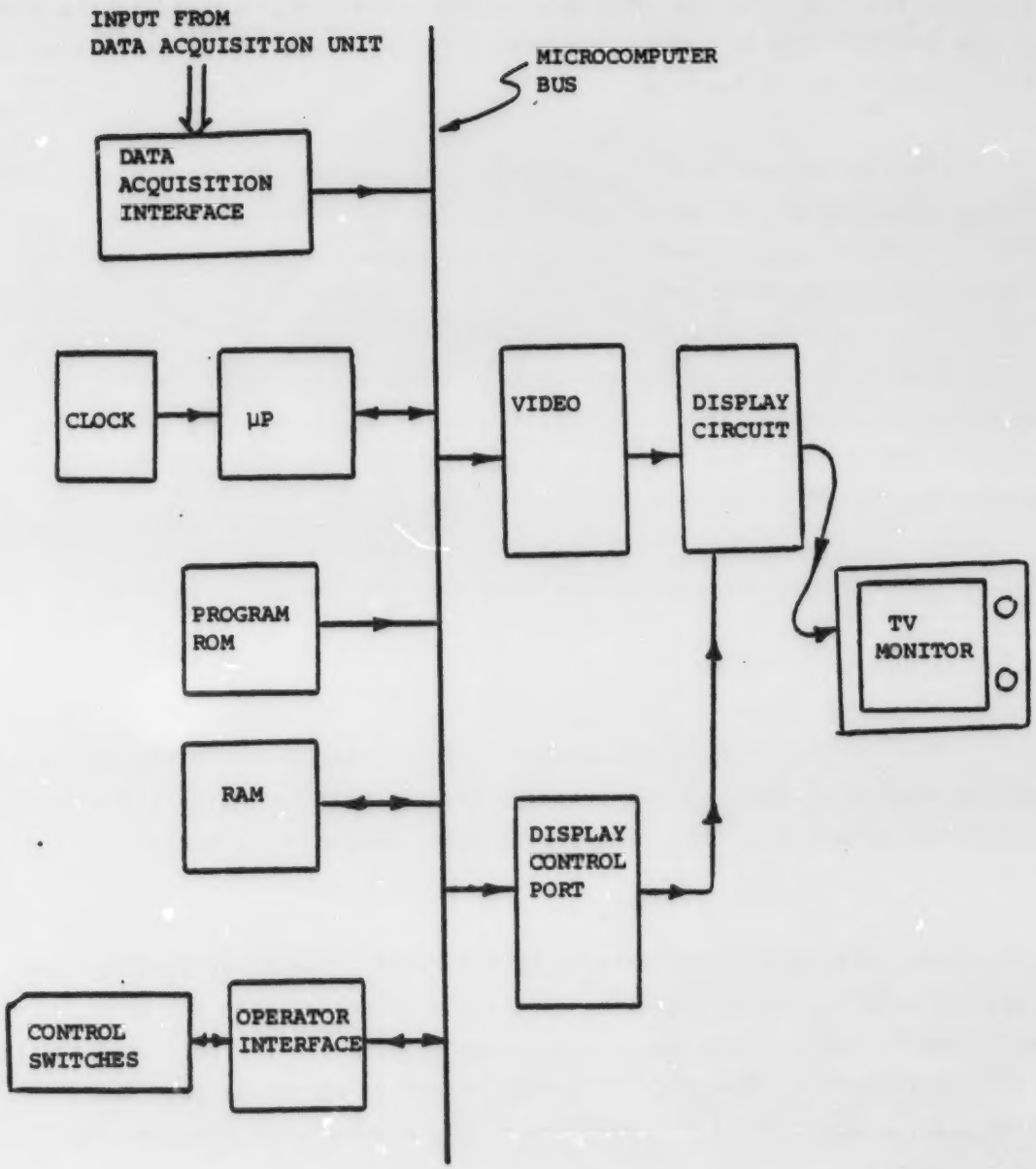


FIGURE 17 CONCEPTUAL DESIGN OF THE RASTER SCAN DISPLAY UNIT

Modulation scheme used for transmission of display data is Frequency Shift Keying (FSK). The communication medium could be anything having the required bandwidth such as telephone lines, radio or microwave link.

The unit is block-diagrammed in Figure 18. As seen, the radar findings are read from the data acquisition ports and processed to the form of the desired display. This information is then sent to the UART modem and the telephone line interface.

Because of the speed of displaying the contents of video memory, the video memory and the display logic is located in the remote display logic and the information transmitted, on the communication link, only updates the content of the video memory.

Figure 19 presents the remote text display unit in block-diagram. As seen, the information is received by the modem and is used to update the display memory. The display logic transfers the content of the display memory to the CRT or other display equipment.

Other remote display options have a similar design structure.

3.4.5 ANNUNCIATOR REPORT UNIT

This option converts the radar findings into the voice announcement of the ongoing traffic. It is purposed for airtraffic control stations where the operators or controllers have other duties while monitoring the traffic.

The unit is block-diagrammed in Figure 20. The radar findings are received from the data acquisition ports and processed into the word addresses by the microprocessor. These word addresses are outputted to the voice synthesizer. The voice synthesizer fetches the words from the vocabulary storage ROM and sends them to the speaker thus composes the announcements.

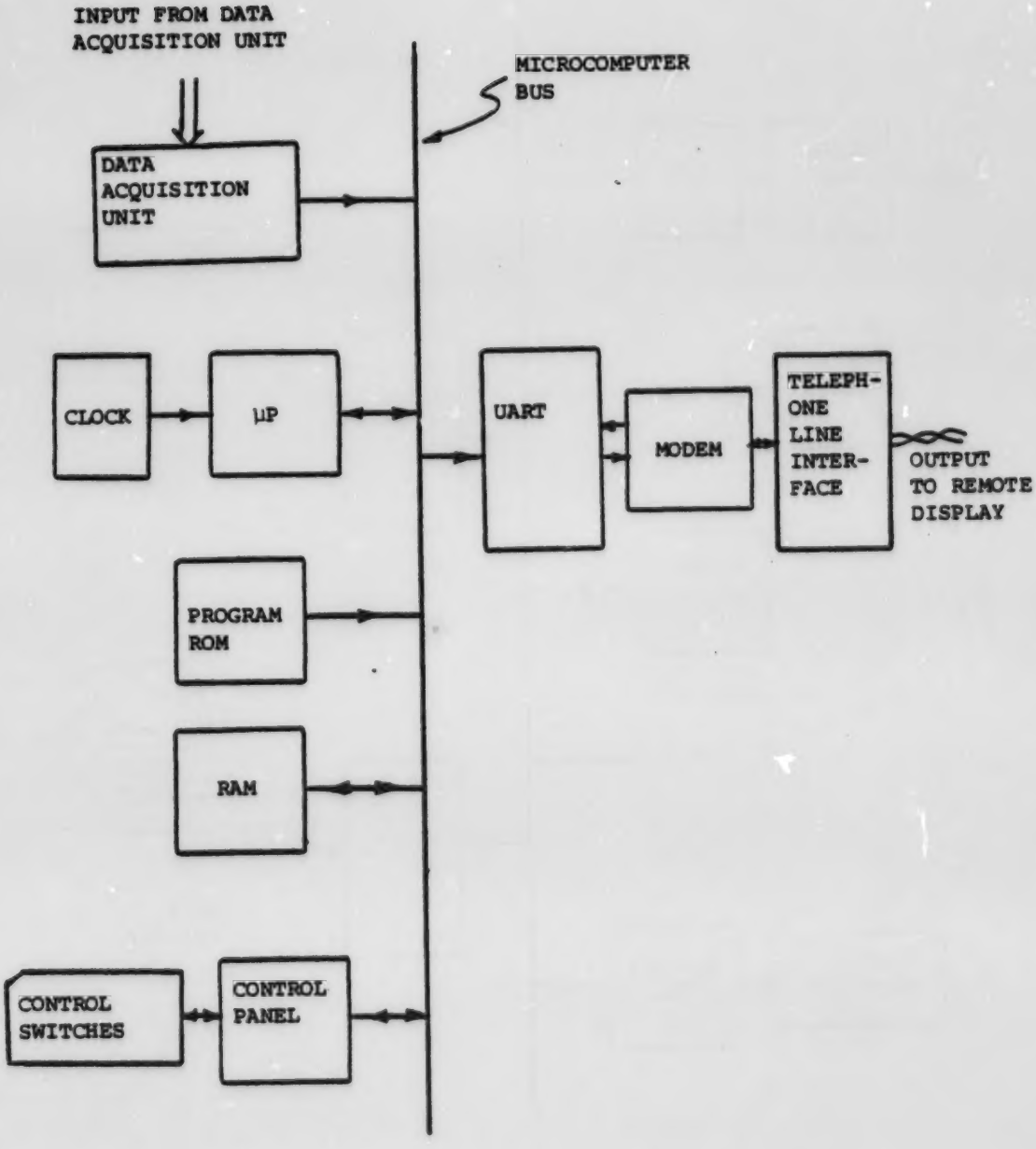


FIGURE 18 CONCEPTUAL DESIGN OF THE REMOTE REPORT UNIT

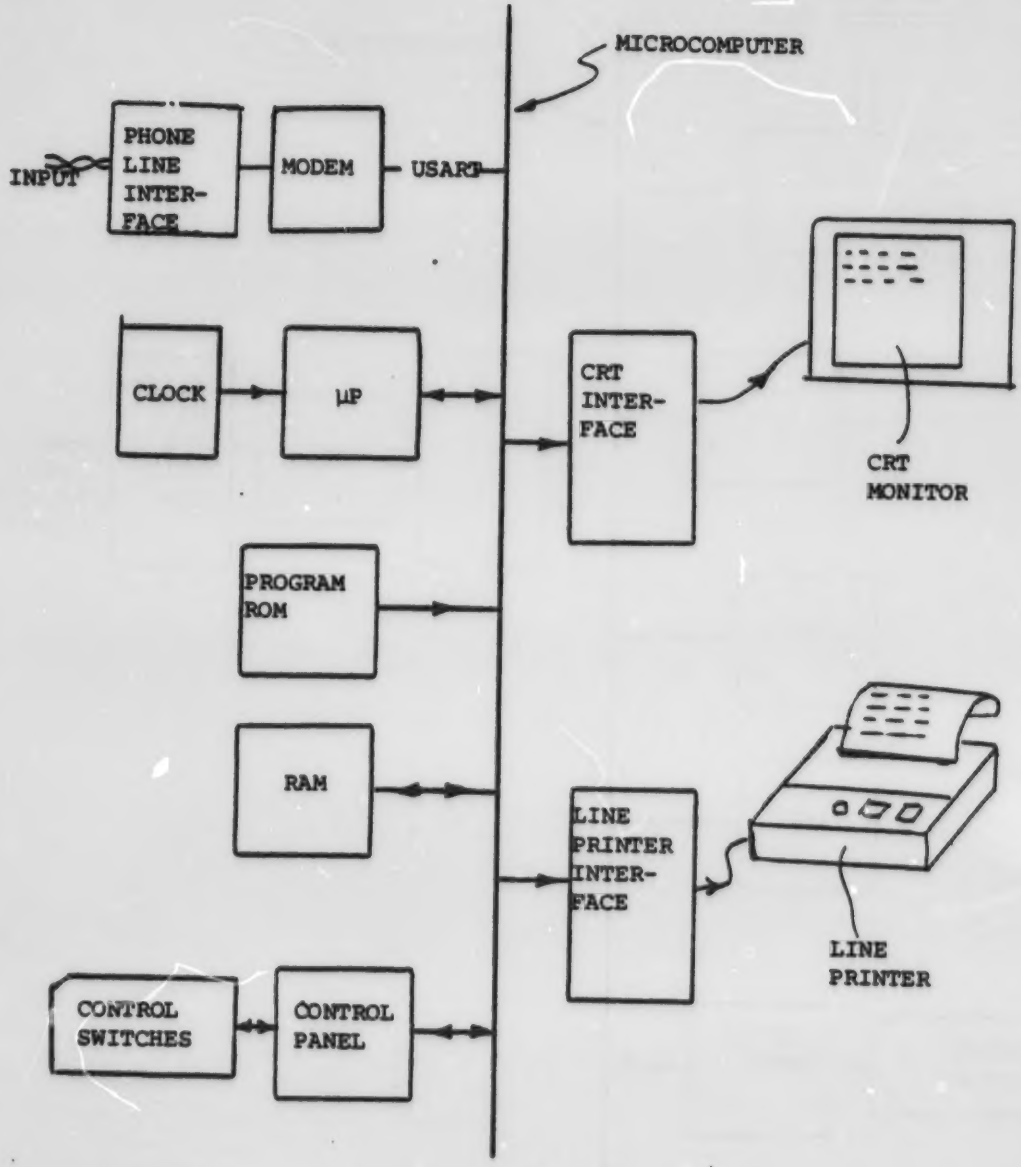


FIGURE 19 CONCEPTUAL DESIGN OF THE REMOTE DISPLAY UNIT

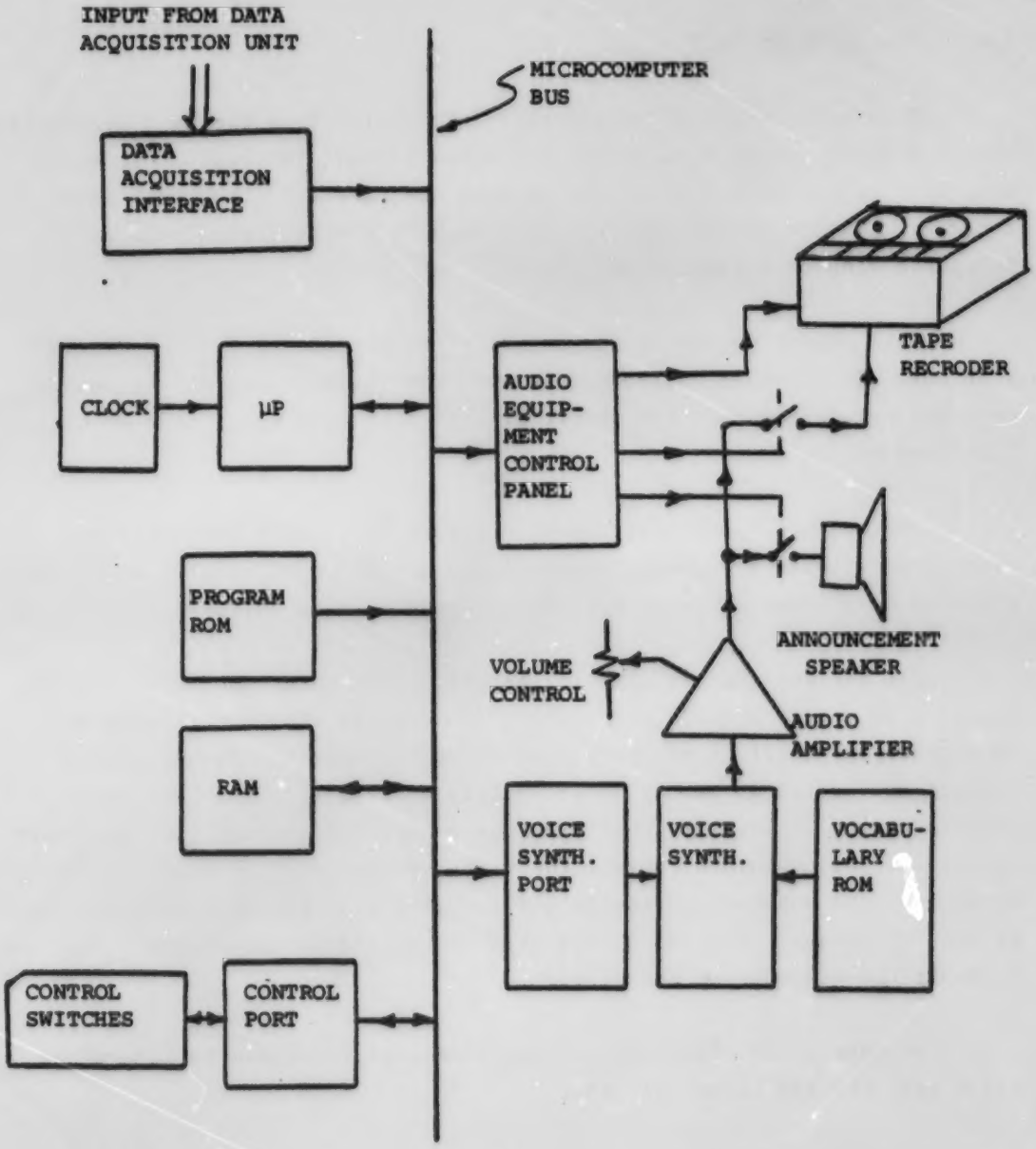


FIGURE 20 CONCEPTUAL DESIGN OF THE ANNOUNCIATOR REPORT UNIT

A tape recorder could also be connected to the unit for logging of the traffic. For this feature again the microprocessor composes the message along with the time and date and sends them to the voice synthesizer, word by word. Also, the microprocessor controls the ON/OFF switching of the tape recorder.

3.4.6 THE TALKBACK UNIT

This unit receives the aircraft information from the data acquisition unit and reports them back to the pilot by aircraft VHF radio. It could also log these communications, along with the time and date, on a tape recorder. The recording can be played back by remote control via a telephone line or a radio link.

This report option is the one originally proposed for the UNAVCOM stations. It provides Unattended service for the aircraft flying in the area and asking for position report by activating the SPI switch on their transponders.

The unit is block-diagrammed in Figure 21. It is basically a microcomputer with peripherals controlling a voice synthesizer, a VHF radio, and a tape recorder. The operational procedure is as follows:

The SSR detected information is read, upon interrupt, from the data acquisition unit. The SSR status port is checked after this interupt. If no operational fault is reported, the radar findings are formed into a message and stored in memory as vocabulary addresses. This vocabulary address string is later fetched from the memory and is loaded to the voice synthesizer port, word by word. The voice synthesizer, in turn, fetches the words from the vocabulary storage and forwards them to the microphone input of the VHF radios. The radios are also controlled by the micrprocessor and transmit the messsage to the pilot.

In case of SSR fault detection, a message is formed to inform the pilot that the SSR is out of order.

The unit could be implemented by a popular MOS microprocessor and a word structured voice synthesizer, such as National Semiconductor's Digitalker™ with a custom ordered vocabulary ROM.

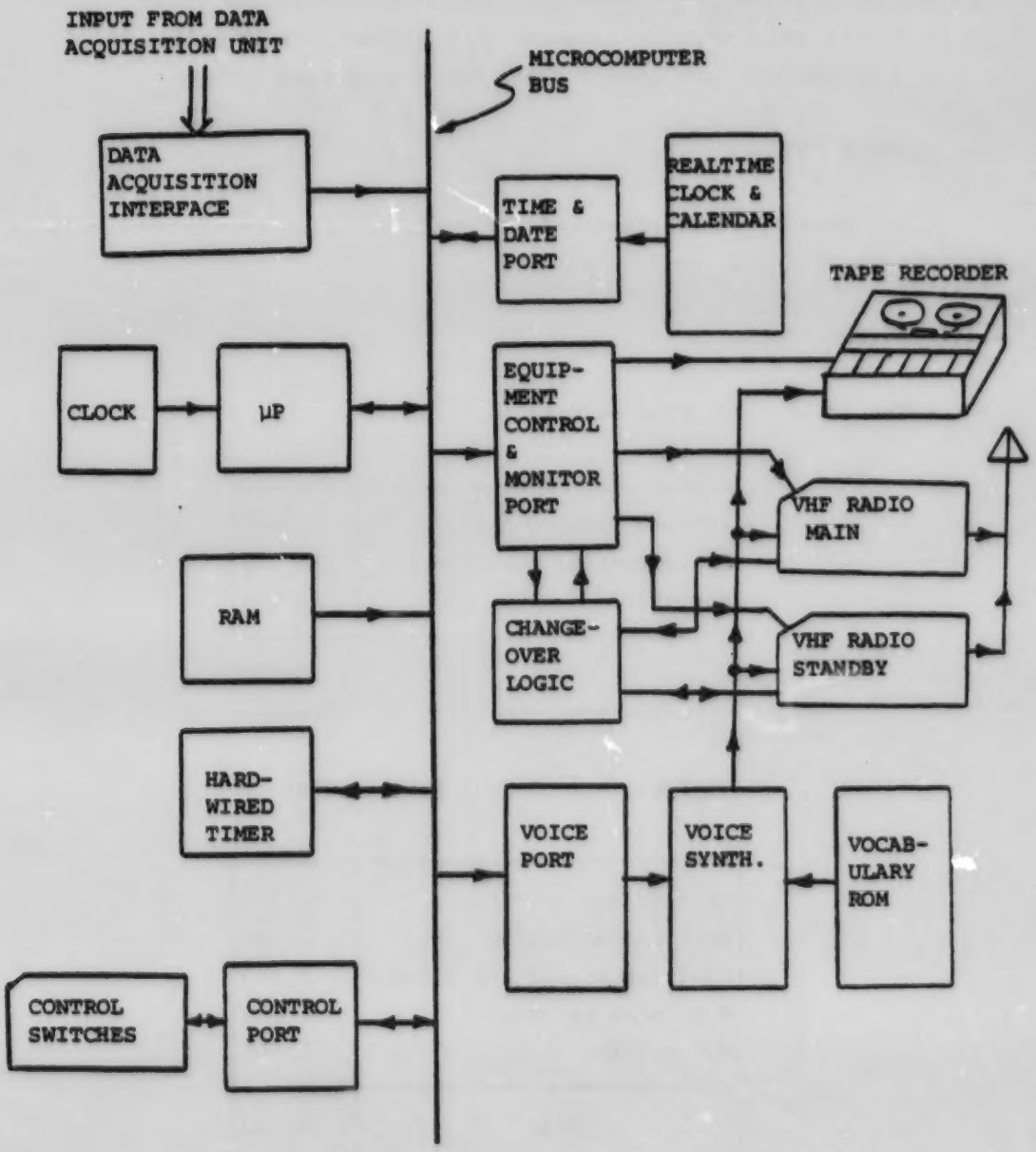


FIGURE 21 CONCEPTUAL DESIGN OF THE TALKBACK UNIT

4.0 COST AND TIME ESTIMATES

The cost and time estimates for low capacity SSR are presented in two languages, i.e.:

- Unit price with development cost spread over 30 units.
- Design and Development costs for a prototype.

4.1 PRODUCT COST

Equipment cost is presented per unit, assuming development cost is spread over 30 units, as follows:

4.1.1 ANTENNA UNIT

The pricing for this unit is as follows:

Antenna (Phased Array)	$ 40,000
Phase control Electronics	60,000
Structure	20,000
TOTAL	$120,000

Table 4-1 E-Scan Antenna Cost

Antenna and roto-feed	$ 10,500
Rotation mechanism	4,500
Position sensor and encoder	2,000
• Antenna pedestal	2,000
• Possible radom	1,000
TOTAL	$ 20,000

Table 4-2 M-Scan Antenna Cost

4.1.2 INTERROGATOR UNIT

The cost of this unit is broken down by module, as follows:

• Transmitter and Receiver	$ 53,000
• Coder	1,200
• Video Processor	1,800
• Fault Monitoring	3,000
• Front panel/controls	1,200
• Packaging	2,500
TOTAL	$ 62,800

Table 4-3 Interrogator Unit Cost

4.1.3 DATA ACQUISITION UNIT

The cost of this unit is broken down by module as follows:

• Garble rejection	$ 1,500
• Frame decoder	1,000
• Shifter/multipler/registers	1,000
• Handshake circuit	1,000
• SPI decoder	1,000
• Range decoder	1,000
• Azimuth decoder	500
• Status report port	500
• Target processor	1,500
• Packaging & mechanical	1,500
TOTAL	$ 10,500

Table 4-4 Data Acquisition Unit Cost

4.1.4 THE COST OF DISPLAY/REPORT OPTIONS

The cost of these units are estimated in the following tables:

• Microprocessor/memory/ports	$ 1,500
• Operator panel & Interface	1,000
• CRT display logic	1,000
• Printer interface	1,000
• CRT display	300
• Line Printer	700
• Software	2,000
• Packaging	1,500
TOTAL	$ 9,000

Table 4-5 Text Display Unit Cost

• microprocessor, memory and ports	$ 1,500
• operator panel & Interface	1,000
• PPI Interface	5,000
• PPI (RCA AN/SPA-4A)	14,500
• Software	1,500
• Packaging	1,500
TOTAL	$ 25,000

Table 4-6 PPI Display Unit Cost

• microprocessor, memory and ports	$ 1,500
• operator panel & Interface	1,000
• video memory	1,500
• Display circuit	1,000
• TV monitor	300
• Software	2,700
• Packaging	1,500
TOTAL	$ 9,500

Table 4-7 Raster Scan Display Unit Cost

• microprocessor, memory and ports	$ 1,500
• USART and controls	1,000
• Modem	500
• Software	1,500
• Packaging	1,000
TOTAL	$ 5,500

Table 4-8 Remote Report Unit Cost

• microprocessor, memory, ports	$ 1,500
• voice synthesizer	500
• Custom Vocabulary ROM	500
• Audio circuit	300
• Speaker & Operator Controls	500
• Tape recorder (optional)	500
• Software	2,000
• Packaging	1,500
TOTAL	$ 7,300

Table 4-9 Annunciator Report Unit Cost

• microprocessor, memory, ports	$ 1,500
• Real time clock	500
• Voice Synthesizer	500
• Custom Vocabulary ROM	500
• VHF radios & antennas	4,000
• Radio controller logic	500
• Tape recorder	500
• Software	2,000
• Packaging	1,500
TOTAL	$ 11,500

Table 4-10 Talkback Unit Costs

REMOTE DISPLAY UNITS

The cost of these units are in the same order of magnitude as the cost for corresponding local display units, for example for remote text display unit the price tag is about $10,000 with CRT display and a line printer.

4.2 DEVELOPMENT COST AND TIME

This cost is broken down into unit and subunit levels. The time schedule for a development program of such a radar, with Talkback option, is presented in Figure 22.

4.2.1 DEVELOPMENT COST FOR THE ANTENNA

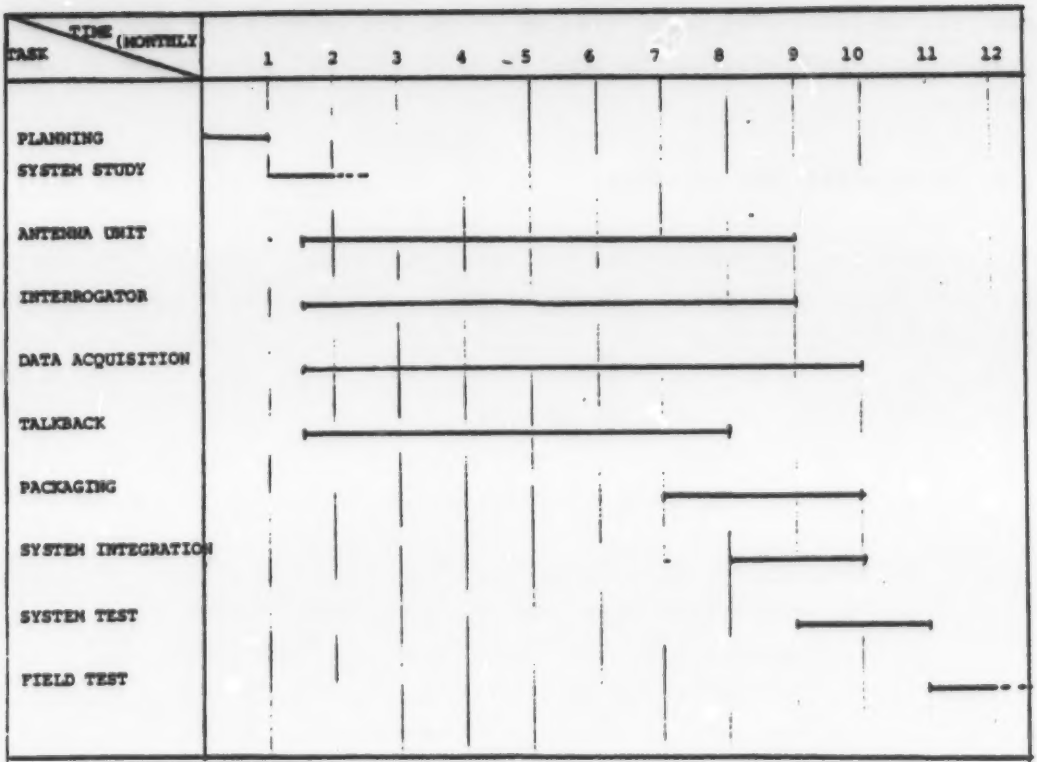
The cost of developing the first prototype of the antenna units is as follows:

Engineering	3,000 man-hr.	$120,000
Mechanical Design	2,000 man-hr.	70,000
Workshop	3,000 man-hr.	75,000
Materials		60,000
TOTAL		$325,000

Table 4-11 E-Scan Antenna Development Cost

Engineering	750 man-hr.	$ 30,000
Mechanical Design	2,000 man-hr.	14,000
Workshop	600 man-hr.	15,000
Materials		10,000
TOTAL		$ 69,000

Table 4-12 M-Scan Antenna Development Cost



Personnel requirement for this schedule:

Project Manager	1
Antenna Engineer	1
RF Engineer	2
Digital Engineer	2
Programmer	1
Mechanical Designer	1
Technician	3

FIGURE 22 TSSR DEVELOPMENT TIME SCHEDULE

4.2.2 DEVELOPMENT COST FOR THE INTERROGATOR UNIT

Engineering (RF)	1,550 man-hr	$ 62,000
Engineering (Digital)	700 man-hr	28,000
Prototyping	1,400 man-hr	35,000
Materials (RF)		47,000
Materials (Digital)		8,000
TOTAL		$180,000

Table 4-13 Interrogator Unit Development Cost

4.2.3 DEVELOPMENT COST FOR DATA ACQUISITION UNIT

Engineering	2,200 man-hr	$ 85,000
Prototype building	500 man-hr	12,500
Materials		7,000
TOTAL		$104,500

Table 4-14 Data Acquisition Unit Development Cost

4.2.4 DEVELOPMENT COST FOR THE DISPLAY/REPORT OPTIONS

Engineering (Hardware)	200 man-hr	$ 8,000
Engineering (Software)	600 man-hr	24,000
Prototype building	160 man-hr	4,000
Material		5,000
TOTAL		$ 41,000

Table 4-15 Text Display Unit Development Cost

Engineering	1,000 man-hrs.	$ 40,000
Prototype building	200 man-hrs.	5,000
Material		20,000
TOTAL		$ 65,000

Table 4-16 PPI Display Unit Development Cost

Engineering (Hardware)	500 man-hr	$ 20,000
Engineering (Software)	800 man-hr	32,000
Prototype building	200 man-hr	5,000
Materials		6,000
TOTAL		$ 63,000

Table 4-17 Raster Scan Display Unit Development Cost

Engineering (Hardware)	200 man-hr	$ 8,000
Engineering (Software)	600 man-hr	24,000
Prototype building	160 man-hr	4,000
Material		5,000
TOTAL		$ 41,000

TAble 4-18 Remote/Report Unit Development Cost

Engineering (Hardware)	400 man-hr	$ 16,000
Engineering (Software)	1,000 man-hr	40,000
Prototype building	200 man-hr	5,000
Materials		5,000
TOTAL		$ 66,000

Table 4-19 Annunciator Report Unit Development Cost

Engineering (Hardware)	500 man-hr	$ 20,000
Engineering (Software)	1,000 man-hr	40,000
Prototype building	200 man-hr	5,000
Material		8,500
TOTAL		$ 73,500

Table 4-20 Talkback Unit Development Cost

Development Cost for Remote Display Units

The development cost for each of these units is approximately the same as the cost for the corresponding local display unit.

4.3 COST OF AN SSR SYSTEM

Any combination of the Display/Report options with the basic SSR (which consists of the Antenna unit, Interrogator unit, Data Acquisition unit and the Power Supply) unit is feasible. The price estimates for the following two examples are presented.

4.3.1 AN ECONOMIC SSR FOR SMALL MANNED AIRPORTS

The lowest priced SSR, intended for a small manned airport, consists of the basic radar plus the text display unit. The unit price (development cost spread over 30 units) is as follows:

• Antenna Unit (M-Scan)	$ 20,000
• Interrogator Unit	62,800
• Data Acquisition Unit	10,500
• Text Display Unit	9,000
• Power Supply	2,000
TOTAL	$104,300

Table 4-21 Unit Price for an Economic SSR

The cost of installation, warranty and operator training is not included and could amount to maximum 20% of the above figure.

4.3.2 TALKBACK SSR FOR A UNAVCOM STATION

Another example of interest is the UNAVCOM TSSR. This system consists of the basic radar plus the Talkback unit, the price tag for the system (spread over 30 units) is as follows:

• Antenna Unit (M-Scan)	$ 20,000
• Interrogator Unit	62,800
• Data Acquisition Unit	10,500
• Talkback Unit	11,500
• Power Supply (DC to DC)	5,000
TOTAL	$109,800

Table 4-22 Unit Price for a TSSR

4.4 DEVELOPMENT COST FOR AN SSR SYSTEM

The examples of Section 4.3 are analysed for development cost.

4.4.1 DEVELOPMENT COST FOR THE ECONOMY SSR

• Development Cost for Antenna Unit	$ 69,000
• Development Cost for Interrogator	180,000
• Development Cost for Data Acquisition	104,000
• Development Cost for Text Display Unit	41,000
• Development Cost for Power Supply	5,000
• Cost of Manuals	10,000
TOTAL	$409,000

Table 4-23 Development Cost for the Economic SSR

4.4.2 DEVELOPMENT COST FOR UNAVCOM TSSR

• Development Cost for Antenna Unit	$ 69,000
• Development Cost for Interrogator	180,000
• Development Cost for Data Acquisition	104,000
• Development Cost for Talkback Unit	73,500
• Development Cost for Power Supply	7,000
• Cost of Manuals	10,000
TOTAL	$443,500

Table 4-24 Development Cost for the TSSR

5.0 POWER CONSUMPTION OF THE RADAR

The power consumption, of the low-capacity SSR, is presented for each unit.

5.1 ANTENNA UNIT

Antenna motor	15 W
Antenna position sensor	5 W
TOTAL	20 W

Table 5-1 Antenna Unit Power Consumption

5.2 INTERROGATOR UNIT

Transmitter	140 W
Receiver	15 W
Coder	5 W
Video Processor	5 W
Fault Monitoring	10 W
Front Panel Displays	5 W
TOTAL	180 W

Table 5-2 Interrogator Unit Power Consumption

5.3 DATA ACQUISITION UNIT

• Garble rejection	18 W
• Frame decoder & shift register	7 W
• Multiplexer & response registers	3 W
• SPI decoder	4 W
• Range decoder	5 W
• Azimuth decoder	2 W
• SSR Status port	2 W
• Handshake logic	4 W
• Code Processor	10 W
TOTAL	45 W

Table 5-3 Data Acquisition Unit Power Consumption

5.4 POWER CONSUMPTION OF OPTIONS

• Microprocessor & support	15 W
• Operator panel displays	5 W
• CRT display logic	10 W
• printer interface	5 W
• CRT monitor	30 W
• Line printer (MX-80)	100 W
TOTAL	175 W

Table 5-4 Text Display Unit Power Consumption

• Microprocessor and support	15 W
• operator panel	5 W
• PPI interface	10 W
• PPI display	150 W
TOTAL	180 W

Table 5-5 PPI Display Unit Power Consumption

• Microprocessor and support	15 W
• Operator panel	5 W
• Video panel	15 W
• Display circuit	5 W
• TV monitor	30 W
TOTAL	70 W

Table 5-6 Raster Scan Display Unit Power Consumption

• Microprocessor and support	15 W
• VSART and controls	5 W
• Modem	10 W
TOTAL	30 W

Table 5-7 Remote Report Unit Power Consumption

• Microprocessor and support	15 W
• Operator panel	5 W
• Voice synthesizer & ROM	5 W
• Audio Amplifier	20 W
• Tape recorder	15 W
TOTAL	80 W

Table 5-8 Annunciator Unit Power Consumption

Microprocessor and support	15 W
Voice synthesizer and ROM	5 W
VHF radios	25 W
Radio and recorder control logic	5 W
Tape recorder	10 W
TOTAL	60 W

Table 5-9 Talkback Unit Power Consumption

5.5 POWER CONSUMPTION OF AN SSR SYSTEM

The power consumption of the two packages described in Section 4.3 is given as follows:

Antenna	Unit	20 W
Interrogator	Unit	180 W
Data Acquisition	Unit	45 W
Text display	Unit	175 W
TOTAL		420 W

Table 5-10 Power Consumption of the Economic SSR

• Antenna	Unit	20 W
• Interrogator	Unit	180 W
• Data Acquisition	Unit	45 W
• Talkback	Unit	60 W
TOTAL		305 W

Table 5-11 Power Consumption of the UNAVCOM TSSR

6.0 COMPARISON OF TSSR AND TALKBACK DIRECTION FINDER FOR UNAVCOM

A Talkback Radio Direction Finder (TDF) could be used in a UNAVCOM station, instead of a TSSR. A comparison between these two is made, in this chapter, as follows:

6.1 OPERATIONAL CONSIDERATIONS

An obvious differnece is the need to carry the SSR transponder, by the aircraft, in order to be able to use the TSSR service. On the other hand, TDF service requires carrying only the VHF radio which is carried by most of the aircraft.

Further, each aircraft using the TSSR service requires a transponder code, by which it is recognized and addressed. Assignments of these codes for more than one aircraft, requires more administration or effort on the pilot's side. This is discussed in chapter 2 and three methods were presented to avoid confusion, namely:

1. Log in with the UNAVCOM Station.
2. Code assignment upon flight plan submission.
3. Pilots' radio conferencing, as a resulted of a warning from TSSR, to dial different codes or activate SPI switch one at a time.

The TDF does not have this complication, but there is a good probability of confusion if the two pilots try to use the service simultaneously. The situation is naturally handled by the two pilots, following traditional practice of two way radio, as to not interfere with the existing communication.

From a navigation point of view, TSSR provides more information to the pilot, i.e., it radios range as well as azimuth bearing angle. It provides a position fix for the pilot and the pilot can arrive at a destination with the shortest possible route. In the TDF case the pilot only receives the bearing angle and needs the service of two more stations to triangulate and know his position. Otherwise, all he can do is to fly from one station to the next until his destination.

Moreover, the SSR system could detect emergency situations, such as air/ground radio failure, and inform a manned station or other aircraft. There is no such possibility in TDF.

6.2 PERFORMANCE CONSIDERATIONS

The SSR is inherently more reliable than DF. This is due to the fact that SSR features a directional antenna reflections are less likely to interfere than the case of TDF. In TDF the bearing angle reported is the vector sum of the direction of the aircraft and any reflections of aircraft radio waves from site structures or other aircraft. This problem also exists in SSR; however, by using side-lobe suppression techniques or monopulse techniques, the effect is more manageable and can be greatly reduced.

Both systems are basicaly line of sight equipment. However, a DF system could sometimes work on the ionosphoric reflection of VHF radio waves and report bearings from farther distances than expected. The SSR, working with higher frequencies, is less affected by this phenomena. From reliability point of view, this feature is not desired and should be considered as a negative point for DF.

6.3 TECHNICAL AND ECONOMIC CONSIDERATIONS

The DF sytem is less complicated and less costly than a full-scale SSR; however, with the concept of the low-traffic SSR presented in this report, the cost and sophistication of an SSR system for UNAVCOM type of applications could be brought down to the same order of a magnitude as a high performance DF. In spite of this reduction of cost, the low capacity SSR has superior performance than DF.

The antenna of SSR is a rotating unit; Therefore, it needs only occasional maintenance. With modern bearings, gear design and lubricants, an MTBF much higher than that necessary for one year maintenance period of UNAVCOM stations can be achived. Moreover, non-rotational, electronically scanned antennas can be designed for SSR but with much higher cost.

The Talkback unit, proposed in Subsection 3.4.6, could be used with either DF or SSR. However, interfacing with DF needs one more feature, which is the electronic record and playback of the pilot's voice. This adds to the cost and complexity of the talkback unit by a factor of about 25 percent.

Lightning strikes at the DF antenna may partially damage the array and, as a result, erroneous bearings will be reported. On the other hand, SSR M-Scan antenna could only be completely damaged and would not function at all. It is believed that, in navigation, no readout is better than a wrong one.

7.0 RESULTS

The conceptual design of the SSR, as presented in the previous chapters, was discussed with potential users of the system. The results of these reviews are as follows:

- The system attracted interest in its capabilities both as a navigation aid for small manned airport and for the UNAVCOM stations.

- There is a reluctance on the part of plane owners to buy a transponder unit and transportation authorities to enforce the use of this equipment. This is the major draw back of using the SSR. The solution to this problem depends on policies of the transportation authorities.

- For UNAVCOM stations, SSRs provide a great deal of capability and operation flexibility. However, unless the transponder problem is resolved by authorities, the Radio Directional Finder alternative is found to be more favorable.

- The low-capacity SSR was found to be very attractive for organizations running their own fleet of aircraft in a particular region, such as defence, off-shore oil drilling, and pipeline projects etc.é For these organized activities, the problems of carrying a transponder and assignment of codes can be easily resolved. However, none of these organizations showed any interest in providing the financial support for development of such an SSR. The interest was to utilize any navigation facilities provided by Transport Canada.

- The idea of developing a low-cost transponder, supporting only mode 3A and C, was found to be very promising in promotion of the application of the SSR concept for general aviation. An initial study by CAL shows that such an economic SSR transponder can be produced at a price of approximately $500 instead of $1,500 for a unit available off-the-shelf today.

8.0 SUMMARY

The concept of a low-capacity Secondary Serveillance Radar (SSR) for applications in small manned airports and for the UNAVCOM stations was studied. It was found that such an implementation is feasible from both technical and economic point of view.

The detailed conceptual design was prepared. Several different display and report options were investigated. These options were designed as close to the implementation as possible. The designs were reviewed with potential users of the radar and their views and recommendations, where applicable, were implmented in the design. The final design is presented in Chapter 3.

The review of the concept, from operational aspects of the air-traffic, revealed some administrative problems such as the degree of madating of the use of SSR transponder on-board the small planes and assignment of codes to them. These problems are identified in Chapter 2, 6 and 7. The net result is the use of SSR for general aviation is strongly recommended if the transponder problem is resolved by transport authorities.

In Chapter 6, the proposed low-capacity SSR is compared with its rival Radio Direction Finder (DF). The ideas presented in this chapter are results of discussions with users of these radars and the air transport experts. It is believed they are very important for decision and policy making by the authorities.

The realization of these designs was cost and time estimated. The results are presented in Chapter 4, both as the development cost to the first prototype and as the product price with development cost spread over 30 units. It was found that a radar of this type could be realized in a product with a price tag of approximately $100,000, with development cost spread over 30 units.

The power consumption of the radar and its options are estimated and presented in Chapter 5. As examples, the power consumptions of a low price radar for small airports with text display option and the Talkback SSR for a UNAVCOM station were found to be 440 watts and 305 watts, respectively.

Further, to broaden the scope, the technical aspects and some cost estimates for a talkback DF is presented in Appendix A.

9.0 RECOMMENDATIONS

The requirement of small manned airports and the UNAVCOM stations are somewhat similar as far as the traffic density and their navigation service is concerned. Therefore, both can be categorized here as navigation stations.

The use of proposed low-capacity SSR, for these stations, is strongly recommended if the transportation authorities resolve the question of carrying a transponder by general aviation aircrafts.

The SSR, by itself, is capable of providing a position fix to the aircraft and the pilots using its service to find the shortest possible way to their destination without flying from station to station.

For the aircrafts not carrying a transponder, the use of a Non Directional Beacon (NDB) transmitter, along with the SSR is recommended. it this case, such aircraft can arrive at their destination by homing from one station to the next, although they cannot obtain a position fix from one station only and they cannot take the shortest way.

The use of Radio Direction Finder (DF) in the station, is a good compromise between performance and ease of operation. This is because DF service is possible by carrying only the VHF radio, onboard the aircraft. However, the nature of the service provided by DF is similar to NDB. It can only be considered complementary to NDB when aircraft does not carry the On-board Direction Finder.

For UNAVCOM stations, either SSR or DF could be used in Talkback mode. In fact, the Talkback computer porposed for TSSR can be programmed to be connected to a DF and work as a Talkback DF (TDF) and vice-versa. This can be done with a few hardware modifications. For the TDF, the only hardware addition would be a solid-state Voice recorder, to record and playback the pilot's voice.

The following Table, lists the recommended equipment for a UNAVCOM station and corresponding aircraft equipment for the desired navigation service. It is assumed that the compass, used by the aircraft, is non magnetic type, this because the service is provided mainly in Arctic regions.

No.	UNAVCOM features	Aircraft Equipment	Navigation Service Provided
1	NDB only	ADF and compass	-Homing from station to station till arriving at destination
2	NDB and TDF	ADF, compass & radio	-Homing from station to station till destination -Redundancy of service (Reliability)
3	TDF only	Compass & radio	-Homing from station to station till destination
3	TSSR	Transponder radio & compass	-Position fixing & flying directly to the destination -Detection of radio failure -Redundancy of service (Reliability)
4	TSSR and NDB	ADF, compass	-same service as No. 1
5	TSSR and NDB	ADF, compass, radio	-same service as No. 1
6	TSSR and NDB	ADF, compass and Transponder	-Position fixing -Homing from station to station -Detection of emergencies and radio failure -Redundancy of service (Reliability)

Table 9-1 Equipment Required for Different UNAVCOM Services

Finally, the use of electronically Scanned Antenna (E-Scan), for UNAVCOM, is preferred if its high cost could be afforded. Such an antenna has no moving or rotating parts and requires far less maintenance. The design and cost estimates of this antenna are presented in the context of Chapter 3 and 4.

REFERENCES

1. "Preliminary Design and Evaluation of a UNAVCOM-II Facility" D. Friberg, and D. Vakili, Canadian Astronautics Limited, 1983.

2. "A Description of the Phase I Automated Terminal Services Concept" U.S. Dept. of Transportation, Nov. 1976 (FAA-EM-76-6).

3. "Radar Handbook" M. Skolnik, McGraw Hill 1970.

4. "Secondary Radar; Fundamental and instrumentation" Peter Honold, Heydon & Sons Ltd. London 1976.

OTHER COMPANIES INVOLVED WITH LOW-CAPACITY SSR

A survey of companies involved in manufacturing low capacity SSR systems was made, in the course of the present study. The following companies seem to havea similar radars to the proposed system; they are listed in order of degree of conformation to the requirements of the proposed system.

1) Cardion Electronics, Woodbury, N. Y. 11797 U.S.A., Telephone (516) 921-7300.

2) Eaton Corporation, AIL Division; Deer Park, N. Y. 11729, U.S.A., Telephone (516) 595-5000.

3) Haselton Corporation; Greenlawn, N. Y., 11740 U.S.A., Telephone (516) 351-4116.